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Marc Moutin, Conference Host

Dale W. Smith, Proceedings Editor

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A Message from the Conference Host

Marc Moutin
IPS2018 conference host

Dear planetarian colleagues, dear friends,
It was a great pleasure to welcome you to Cité de l'espace last July for the 24th IPS conference, five days of intense and fruitful work and exchange ! Many of you came to Toulouse as we were 570 participants from 52 countries. Your many thank you messages after the conference were really highly appreciated after 3 years of hard work to prepare this important event. I would like to thank you very sincerely for your participation and enthusiasm, making the conference a great success. Hoping to meet you in Edmonton for « Big Sky » IPS2020 conference

Shawn Laatsch
IPS Past President

Dear Friends and Colleagues,
Merci Beaucoup and thank you for making IPS2018 at Cité de l'espace in Toulouse, France an incredible professional development event! It was truly a wonderful international exchange with 52 countries participating in numerous ways. I hope you enjoyed your time and met many new colleagues in our field and developed connections for future collaborations. This event would not have been possible without the incredible support of our host – please join me in thanking them again. Each one of these conferences create special memories and my wish is these continue to inspire you in our planetarium field. I look forward to seeing you in Edmonton, Canada for the next IPS conference in 2020!

Note from the Editor

These Proceedings contain texts for many of the papers given at the IPS 2018 conference in Toulouse, France.

I thank all authors who contributed texts of their papers and the Cité de l’espace for its cooperation. We have left the texts in the format provided by the authors rather than editing them into a uniform appearance.

The page numbers in the Table of Contents refer to the page in the PDF folder of the Proceedings. Clicking on a paper’s title or author will take you directly to the paper.

Grateful thanks to the conference organizers and sponsors and to all participants in this landmark IPS conference. Thanks to the organizers for their extensive efforts in collecting these texts and to Léo Réby for preparing the folder of PDFs to send to me for compilation into this document.

Dale W. Smith
Proceedings Editor & IPS Publications Chair
Professor & Planetarium Director, Bowling Green State University
April 2019

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Scientific Visualization Literacy: sensing in the context of the Universe

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BIOGRAPHY

After graduating with her MFA in Electronic Visualization at the University of Illinois at Chicago, Julieta joined the Space Visualization Laboratory at the Adler Planetarium in Chicago. She has since worked at the 'Imiloa Planetarium in Hawai'i and is finishing her Ph.D. with the Planetary Collegium at the University of Plymouth, UK.

ABSTRACT

As models are built about the Universe to replicate the "multi-sensory" data gathered by instruments, the natural biases we hold in processing what we perceive, by having a human body on a planet, shape our understanding of how human perception works, which is the foundation of how to explain the data we share to better understand the Universe we all live in. This foundation challenges us to reach a higher level of proficiency, that is, scientific visualization literacy, as well as developing the aesthetic and scientific collaborative endeavors that are necessary in working with professional in various disciplines. Furthermore, scientific visualization literacy requires a sense of being that is able to bridge the gap between individual and community identity –as culturally construed for social stability– and ever ongoing scientific discoveries.

INTRODUCTION

When we think of the senses and how we individually move in space to navigate or handle objects over time, we can understand how unique each of our lives are. We have all navigated to this place in time in Toulouse with many different experiences that inform how we think and act. Yet we have a common understanding that aspects of experiences that we have come from the kind of organism we are (human), and a general experience of the planet we live on (Earth), including the present time and space we share right now. But our experiences are different indeed and they are cumulative in each of our lives. After working at the Adler Planetarium in Chicago for eight years, often flying through scientific visualizations and data from other planets, I arrived to the Big Island of Hawai'i in 2016 to work at the University that year, and my friend drove me to see the active volcano. My first reaction was "it looks like Mars".

Even as humans on planet Earth we experience variations in relating to space. For the most part we experience gravity the same, and we move over our planet's surface in two dimensions: sideways or forward. But when I worked in Hawai'i, I went into the water to snorkel around, above and under fish, turtles and coral. The old man at the diving shop in Hilo asked me about what I do, and when I mentioned Virtual Reality, he said "you know… diving is 3D" describing the experience of moving with your own body through space. Another thing that I did while in Hawai'i is walk on somewhat fresh, but no longer super hot, lava. We do not normally think of the ground as shifting because most our experiences are on a solid ground which does not move, until it is in liquid form as in lava, or there is an earthquake, and suddenly our decades old home and historic centenary constructions collapse or are taken away. Experiencing lava thus accelerates geologic time for us because we tend to map our experience of the world to stable objects or fixed points in space. On the other hand, our planetarium experience easily traverses space and time to see that everything is changing, even if very slowly, which may give us enough information as to how weak or strong our solid ground assumptions are.

We face the present with our previous experiences, measuring with our body and its internalized knowledge whether things seem similar to what we have perceived before, in the way we have perceived things before, or how we have conceptualized them. This is what I will attempt to structure, because I think that as a community, we need to move further on how we present and explain scientific visualizations. For the convenience of readers this short paper is adapted from a presentation to a narrative format. I will start by addressing the concepts of virtuality, subjectivity and simulation in relation to the notion of experience. Then I will describe how the senses work, how devices extend the senses, and how media build experiences –in particular when utilized for scientific visualization–. Finally I will address how these experiences afford us to inhabit greater spatial and temporal scales and what that may mean to our human experiential repertoire.

I. VIRTUALITY

Alva Nöe wrote that “pictures construct partial environments (… and) correspond to a reality of which, as perceivers, we have a sensorimotor grasp,” a “kind of virtual space” that draws “sensorimotor skills.” (Noë, 2004, p. 178). This observation infers that we already inhabit virtual reality because we cannot see all the sides of an object at once, so as we move around when we see one side, we have created a virtual model in our heads that helps us understand the three dimensional form of an object. From this understanding, it is clear that I may not arrive to the same model of a space or of an object as another person if some of the experience is missing, or the missing parts of the experience are different from one person to another. This because our points of view are different since people at human scale occupy an exclusive spot in space with its corresponding dynamic point of view.

II. SUBJECTIVITY

One of the things that this unique point of view affords each person a subjective experience which is “ (…) the nature of our bodies, the constraints on our perception, and the structure of our consciousness give prominence to the CENTER-PERIPHERY organization of our experienced reality.” (Johnson, 1987, p. 125). What is first person experience and why is that relevant to planetarium shows? The subjective experience or first person experience is that of a single point in space and time. In first person experiences, as in planetarium shows, we are designing a view of the Universe from a single point in space. We are scaling not just space and time to planetary or galactic scales so we can understand spatial and temporal relationships among celestial bodies, but also the point of view itself so we can understand what having a place in space at a certain scale means.

It is important to understand what scaling the point of view entails. Scaling a point of view does not only mean that things around oneself become smaller or larger than human scale and the environment around that point of view has different rules. Scaling the point of view also changes the experience from personal to collective. Think of the subjective experience of a person, or three people in a car where the people share the point in space of the car when driving on a certain street; or a neighborhood and the area in space of all the people that live there and how they may face the same weather pattern as in rain, heat wave, tornado, tsunami or earthquake; or a boat at sea where the people on it are rocking at the same pace. Each of our planet’s two hemispheres have seasons in common and our planet experiences the moon’s phases as an event of planetary subjectivity. On an even larger scale our solar system subjectively carrousels around the center of the Milky Way which is similarly pulled around the Cosmic Web. Subjectivity scientifically visualized can get pretty big indeed.

III. SENSES

Architect Pallasmaa describes the purpose of constructed spaces like this: “The ultimate meaning of any building is beyond architecture; it directs our consciousness back to the world and towards our own sense of self and being.” (Pallasmaa, 2005, location 187) Senses do not react alone to spatial and temporal experiences. We humans are multi-sensory creatures that have evolved to live in the planetary environment of Earth, and in doing so, have slightly specialized to various environmental variables such as weather, altitude and seasons. From there, we are not an input output body device but perhaps a simulation device that each of us builds with the perceptual and motor capabilities that we have in common. The discipline that understands how the senses are related to each other to build simulations as a practice is that of the arts.

IV. SIMULATIONS

We simulate all the time: “In every waking moment, you’re faced with ambiguous, noisy information from your eyes, ears, nose, and other sensory organs. Your brain uses your past experiences to construct a hypothesis— the simulation–“ (…) “the default mode for all mental activity.” (Barret, 2017, pp. 26-27) We experience simulations most of our waking lives because we simulate sensations inside our bodies with the aid of our memories of past experiences, and also with the concepts we have built into our thoughts, in order to understand what is happening and predict what may happen after the present, so we can be prepared to act to it. This is a relevant understanding to have when we share models of the Universe, creating externalized experiences with them. These simulations are external versions of what we already do inside our bodies.

V. AESTHETICS

From an experiential point of view, I would like to define aesthetics as an understanding of corresponding patterns between the body, with its senses and motor capabilities, and the environment including the practice of astronomy. In other words, I understand the people in one geographical location may share a general common aesthetics, conditioned by the qualities of the environment in which they live. I consider aesthetics as the sensory motor experiences of the environment that inform the individual intuition each of us possess. Besides sharing the kind of body and kind of planetary environment we inhabit, being able to walk, swim and execute various gestures to communicate with each other, we also share internal gestures that "can influence our behavior before they reach the threshold of awareness.” (Petitmengin-Peugeot, 1999 p. 72): “Cartesian doubt, Phenomenological reduction, etc., are all such gestures” (Petitmengin-Peugeot, 1999 pp.44-5) This is an important aspect to pay attention to (that we share pre-intuitive gestures) when making assumptions about spatial and temporal aesthetics, as embodied by cultural astronomy developed in different geographies around the world as well as today’s electronic media constrained by modern devices.

VI. MEDIA

Perhaps the accelerating pace of media development in the past century that do not address all our sensory-motor capabilities have led us to see our senses as independent brain body environment loops. The popularization of single view shared devices such as television have also perhaps conditioned us in the past to believe that we all see the same point of view in real life, and encourage mistaken assumptions about other people's experiences that are hard to overcome. But today we have not only visual devices, sound devices or tactile devices but integrated devices that include more senses working together as is proprioception to different degrees, and surround, dynamic and collective point of view as in the case of planetarium domes and large display-based virtual reality (VR) environments. These devices allow us not only to externalize internal models of the world and the Universe, but to experience shared simulations, some of which are scientific visualizations based on data. This is why people who have experienced VR or even augmented reality (AR) with their mobile devices come to planetariums with a different expectation from media than people who have not experienced VR or AR.

VII. SCIENTIFIC VISUALIZATIONS

Scientific visualizations are taking extra sensory data and creating simulations we can all experience together so we can think together about the relationships in the data. I believe these experiences are more important than most people suspect and I would like to see a deeper understanding of what the experiences we are offering mean to our visitors. It has taken me a while to understand how much I took for granted in regards to my own training as an artist and a designer, in terms of understanding my own perceptuo-motor capabilities. When we sense and act within a space, the space tells us about what we are, and who we are. In a way, when we are presented with a constructed experience through a device, we are given a role, a sensory-motor assemblage that tells us who we are: a bird, a plane, or a cosmic super human that traverses the Universe at will.

VIII. EXTENDING THE SENSES

I see astronomical scientific visualization in the light of what biologist Jakob Von Uexküll described as the discipline that has extended the human experience or Umwelt the farthest (Uexküll, 1957). He wrote so before we had travelled beyond the Earth's atmosphere. While telescopes extend human vision and detectors like LIGO extend into a sense we do not have, capturing gravitational waves, scientific visualization in modern planetarium, VR and AR devices enable us to construct experiences from data that we cannot grasp with our bodies as is.

While working at planetariums I was often asked if the scientific visualizations were 'lies'. Because "The most fundamental values in a culture will be coherent with the metaphorical structure of the most fundamental concepts in the culture" (Lakoff and Johnson, 1980, location 385), I see the need to educate the public about how the aesthetics of the human body is being utilized to experience what our bodies cannot reach because of spatial and temporal scales, and why we need to learn to read sensory motor representations as much we read words.

IX. CONCLUSION

Scientific visualization literacy entails understanding how our multi-sensory body perceives and acts in the world, so we can create shared experiences involving extra-sensory data, that is, data that goes beyond human spatio-temporal experience. Immersive and collective scientific visualization, as is the case in planetariums, is at the forefront of this collective human experience. By articulating the construction of spatial relationships at different scales in the Universe, and choreographing the point of view in which we perceive space and time, the experience of a planetarium can help us further reflect about how we inhabit our individual and immediate community spaces differently at each scale. In gaining awareness of how point of view, space and time change at these different scales, we may gain an understanding of our own individual constraints and potentialities to better orient our senses and inform our actions.

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Technical challenges for the visualization of massive data such as Gaia catalog

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BIOGRAPHIES

Joining RSA COSMOS in 2011, Reynald Arnerin is Senior R&D Project Manager on the SkyExplorer software.
Graduated with a master degrees specialized in computer graphics, he worked in collaboration with OBSPM and INRIA Grenoble to develop a physically based real time simulation of galaxies.

ABSTRACT

Scientific data visualization in planetariums has gained a growing interest in the past few years.
As astronomical and simulation data are becoming more and more accessible, it is necessary to present such content to the public.
However handling massive data in real time application is really difficult in terms of data storage, performance and relevance of displayed information.

We use the example of the Gaia catalog containing 1 billion stars to show the technical challenges and explore some ideas to overcome these.

INTRODUCTION

Showing scientific content in planetarium is important. It allows laboratories to present observation results from space missions (e.g., GAIA, JUNO) or astronomical simulation (e.g., GALMER).
Scientific data are more and more massive and abundant: pictures, topography data, objects catalogs, or various structures (e.g., Laniakea). In terms of quantity of information the upcoming Large Synoptic Survey Telescope aims 30 TB a night where SDSS was only 116 TB in its lifetime (1998-2009) [1].
Astronomy has entered the Big Data era with all the benefits brought by Data Mining, Data Visualization, etc.
But these massive data are hard to store, hard to manipulate and hard to render in real time.

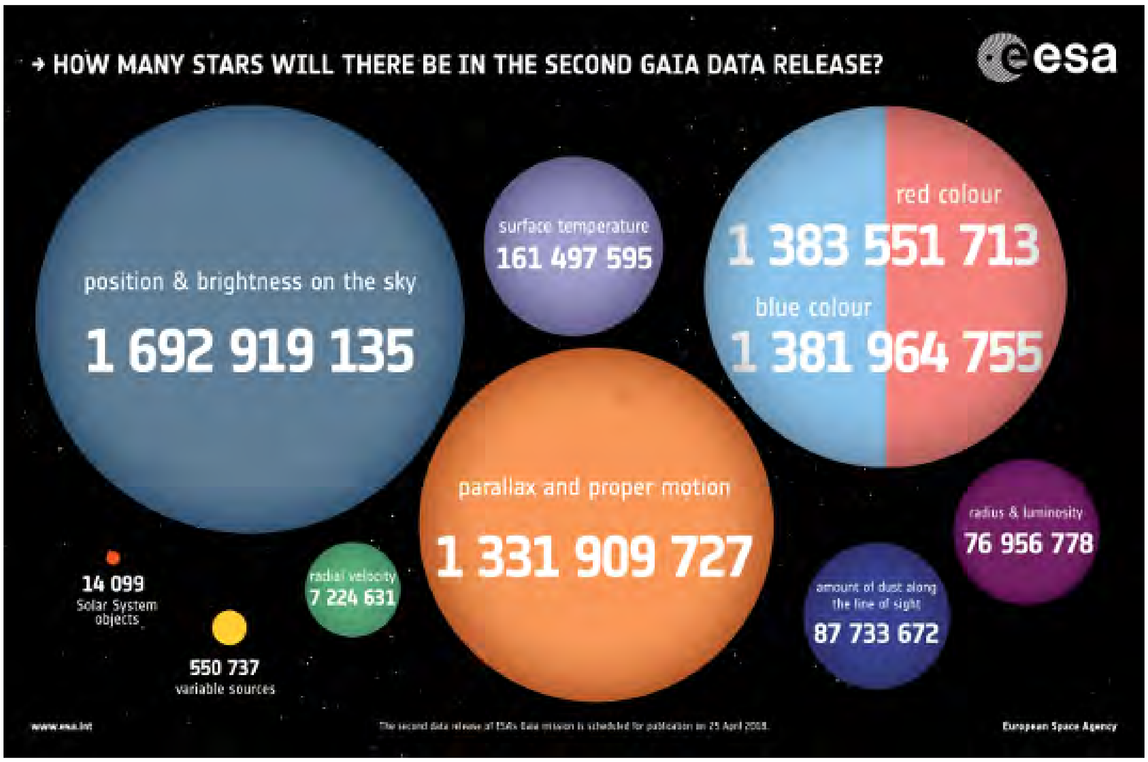

Figure 1 – The image shows numbers of stars in different categories included in Gaia DR2. – 2018, ESA

I. LIMITATIONS

I.1 Memory footprint

Massive data can occupy hundreds of gigabytes or terabytes. It requires a huge amount of memory and it is the first limitation which makes it difficult to use these types of data as is (e.g., Gaia DR2 is 588 GB).

Modern consumer computers equip

8Go of ultrafast graphical memory (VRAM)
16 to 32Go of fast short term memory (RAM)
2 to 4 To of storage memory (Hard Drive)

Using more memory is quite the brute force solution and can be really expensive for planetariums.
Of course, a great part of data published is not relevant for our purpose (error margins, very specific data). Hence this part can be ignored and can save us a lot of space. A selection must be done before giving them to the planetariums.

Nevertheless, these data still occupy quite a lot memory. Even if removing a great deal of data, it can still be too much to process in real time.
For example, Tycho-Gaia catalog in a binary and filtered form was dozens of MB. We can expect Gaia DR2 to be dozens of GB, hence cannot fit the VRAM at once.

I.2 Performances

Computational power is limited. Even if we could load the whole content of the data, CPU and GPU have a lot to do in 16ms (1/60 seconds). As a general rule of thumb we try not to render more than a dozen million primitives with the graphic card to maintain high framerate at high resolution.
This is even harder when data are dynamic (time or position related), when special rendering is necessary (e.g., PSF, semi-transparent layers, volumetric rendering) which causes fillrate problems or too much draw calls. Running real-time simulation on these data (e.g., hydrodynamics, N-body simulation) can also be costly in terms of computational power.
When rendering in real time the performance bottleneck can be found in several steps of the pipeline: CPU, GPU, memory transfer speed.

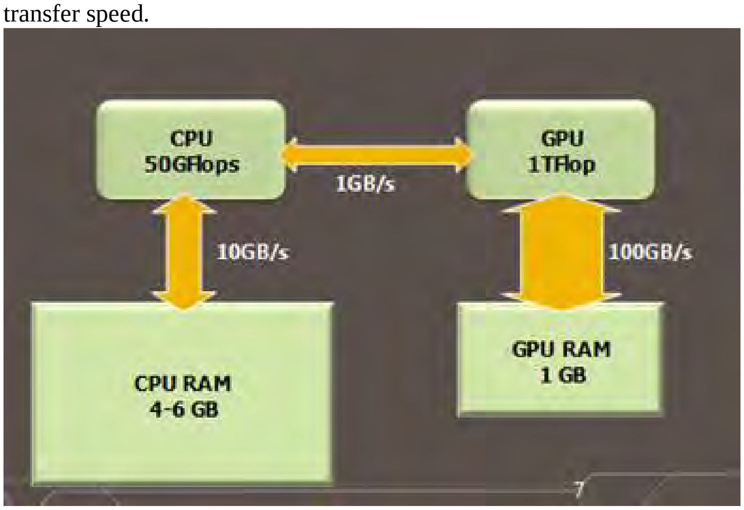

Figure 2 - Memory transfer bottlenecks. - 2012 thebytekitchen.com

I.3 Readability

Massive data can also be hard to show and can be quite tricky to present clearly to the audience.
Lot of data means lot of layers, lot of text, overexposed or saturated colors.
Data Visualization field aims at tackling those challenges but additional computational power or metadata might also be needed to overcome these situations.

Figure 3 - Example of unreadable star label display.

II. HANDLING MASSIVE DATA IN REAL TIME

According to Moore’s law on semiconductors [2], we can expect more computational power and data storage capabilities in the future years. But this means frequent expensive hardware update. And as explained earlier, astronomic data are also getting bigger and bigger.
Hardware limitations always have been the main challenge in real time rendering and a lot of tricks and optimization were developed to address them.

II.1 Faster rendering

Many acceleration structures were developed to organize the data in order to minimize unnecessary processing and memory fetches (i.e., lazy evaluation) and make it efficient on the hardware it runs on (e.g., mechanical hard drives, GPU).
Octrees, quadtrees, kd-tree, Bounding Volumes Hierarchy enable efficient culling. Using these techniques, we can ignore data that are outside of the field of view, too small or to faint to be seen without any impact on the final image. Even though dome’s wide field of view is not ideal to hide groups of data, it has a tremendous impact on the performances and allows to stream data efficiently on demand.

Another source of performances gain is parallel computing. With CPU equipping 6 to 8 cores or the massively parallel architecture of GPUs, we can exploit these resources for real time rendering.
In fact GPU is especially good at processing large data and updating them each frames, making shader programs often mandatory for our purposes.

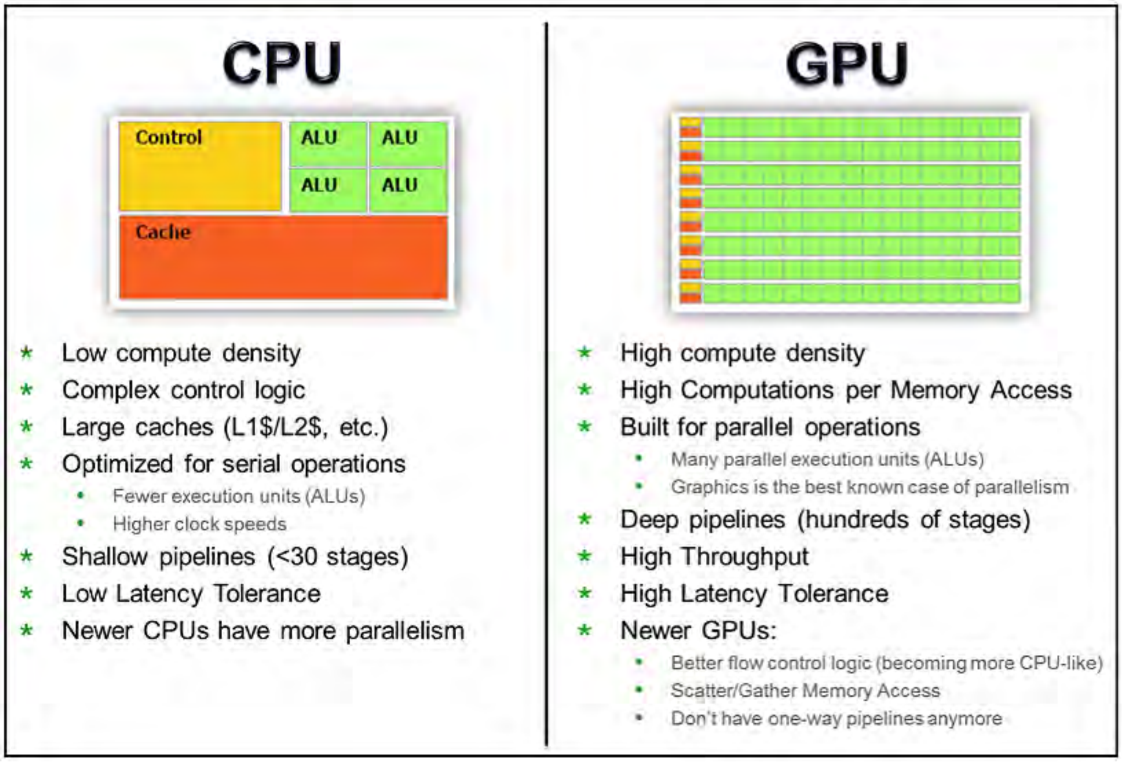

Figure 4 - CPU vs GPU. - 2014, Embedded Computing Design.

Removing aliasing artifact is a good opportunity to get rid of data. Rather than using expensive anti-aliasing techniques we can remove data which are known to cause aliasing before they are rendered thus saving data fetching and processing. However this must be done carefully to avoid visual popping.

It requires some expertise to arrange the data and customize the rendering engine. Other methods such as lower frequency updates or downsampled rendering might be used in certain cases according to the bottleneck location.

II.2 Illusion of data

When data are very massive the visual impact in displaying the exact values at the exact location is often overestimated. If you want to show a forest you don't need to store every leaves. Of course our goal is to display scientific data as accurately as possible. But it can be seen that the visual impact of each data can be significantly different. For example the accuracy required for faint stars is far less critical than bright stars which are forming well known patterns.

The purpose of procedural techniques is to replace high frequency details with data produced on the fly. These data are not stored hence reducing the memory footprint and memory transfer, but they must keep the same statistical properties as the original data to maintain time and space consistency. This is a powerful tool for flyby sequence where data are needed for a short time only.
Fading between procedural content and true data can be visually acceptable. So it can hold the fort while true data are uploaded and shown.

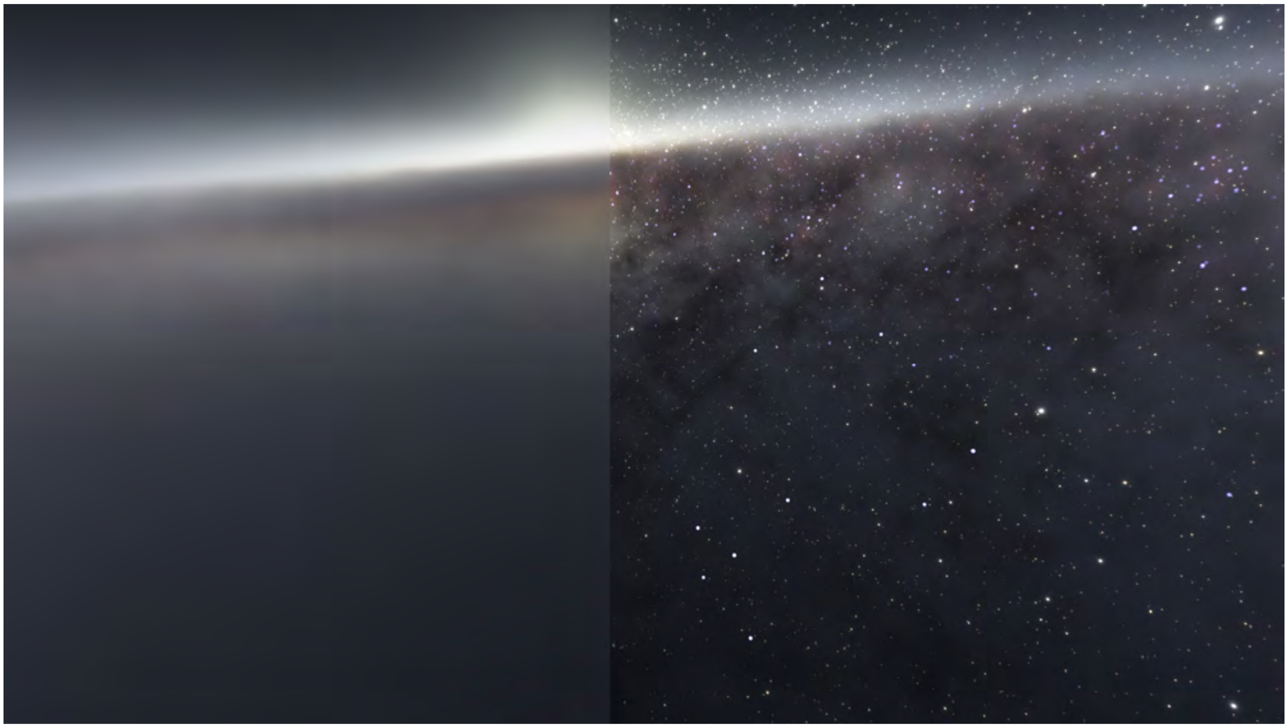

Figure 5 - Dramatic procedural amplification of galaxy using statistical models. – 2016 veRTIGE.

Merging primitives with low variance can be an option too (i.e., Level Of Details optimizations). From a distance, a large field of star looks like a continuum and can be rendered as a set of bigger particles or volumetric model. Once again, low detailed primitives must keep the same statistical properties as the high detailed one to ensure smooth transition between the two.

CONCLUSION

Hardware and algorithms advance is beneficial for the purpose of rendering massive scientific data. But a strategy must be developed specifically for each set of data according to their relevance and their impact on screen.

ACKNOWLEDGMENTS

The veRTIGE team : Frédéric Arénou, Fabrice Neyret, Mikaël Lemercier, Yannick Boissel.

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The perseid meteor shower

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BIOGRAPHIE

Laurent ASSELIN is planetarium presenter for 18 years. Animate sessions for all kind of public. Planetarium sequences programmation. Foreign presenters formation on our planetarium system. Popularization writing and astronomical comic strip drawing for local magazines. Co-direction of our last planetarium production "Lucia, the secrets of shooting stars".

ABSTRACT

Each year, as August begins, most of us as are scrutinizing the celestial vault in order to observe shooting stars. Our presentation will drive us, far from Earth, to comet Swift-Tuttle. Let's follow it on its way through the solar system until it will cross the Earth's orbit. The thin dust particles it leaves will give birth to brief luminous trails that appear to hail from Perseus constellation.

INTRODUCTION

The perseid meteor shower is the most famous period of the year for the observation of shooting stars as it takes place during the summer holidays (in the northern hemisphere !). Many people are waiting for this night to observe the sky but not many knows why it's happening. We will follow 109P/Swift Tuttle comet nucleus through the solar system in order to understand the link between comet dusts, shooting stars and Perseus.

I. COMETS

I.1 109P/Swift-Tutlle

This comet is a periodic comet which orbit stretches from 0.95 a.u (perihelion) to 51a.u (aphelion) from the sun. It travels its orbit in 133 years on a very tilted orbit (113°). 109P/Swift-Tuttle comet is very impressive with its 26 km wide nucleus.

I.2 Composition

For a few decades, different space probes (Giotto, Deep Impact, Stardust or Rosetta) have been send into the solar system to seek the comets nucleus out. The comets coma are made of water vapor, carbon dioxyde, dioxygen, and many small organic molecules made of C, H, N and O.

I.3 Orbits

Every 133 years, as the comet comes near the sun, it becomes brighter as view from Earth. Its temperature slowly increases. Gas and dusts are gradually released in space. The icy nucleus is wrapped by the coma. Two long tails made of gas and dust may appear. Year after year, in mid-august, on its orbit around the sun, our planet will cross dust clouds leaved by the comet during the past centuries..
In the future, comet Swift-Tuttle will cross our planet in 2126 leaving some more dust nearby Earth' orbit.

II. WHY ARE THEY CALLED "PERSEIDS" ?

Every year, around the 12th of August, the Earth passes through clouds of dusts leaved by the comet during the last centuries. These dusts enter our atmosphere at very high speed (59km/s). As seen from Earth, shooting stars appear as dusts burn up.
By an effect of perspective due to the Earth' motion, those meteors seem to come from the constellation of Perseus. That's why we call them Perseids.

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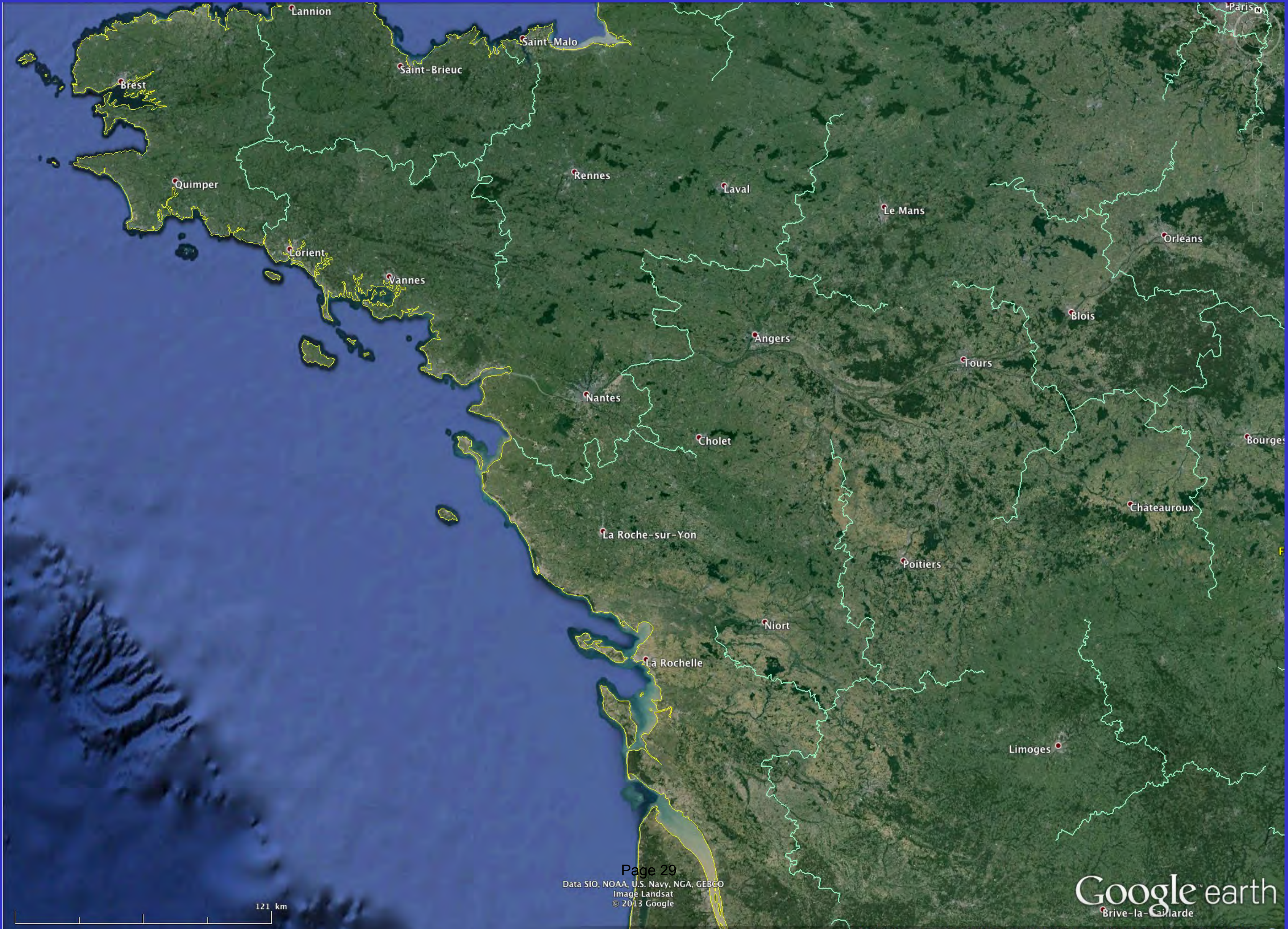

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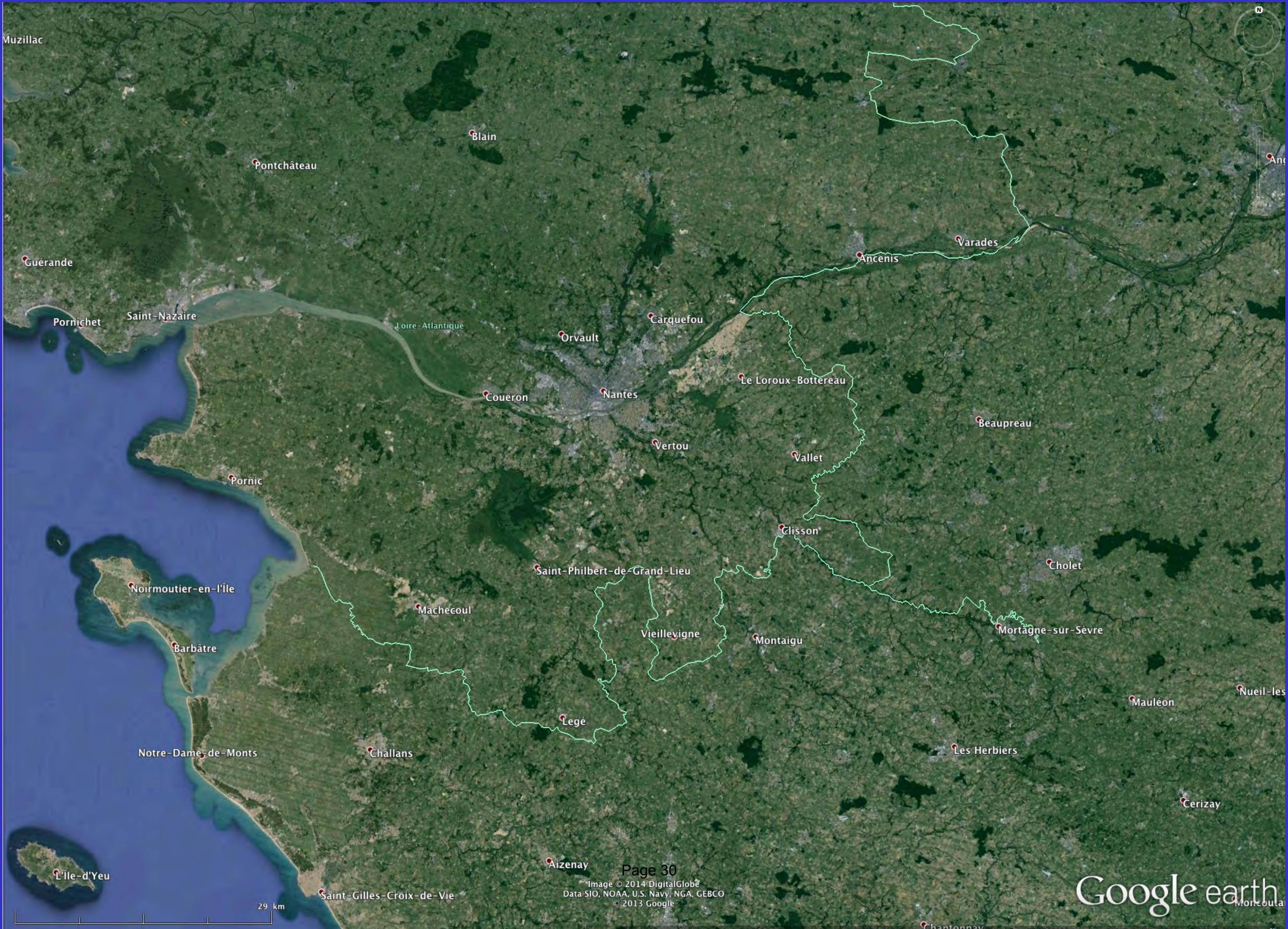

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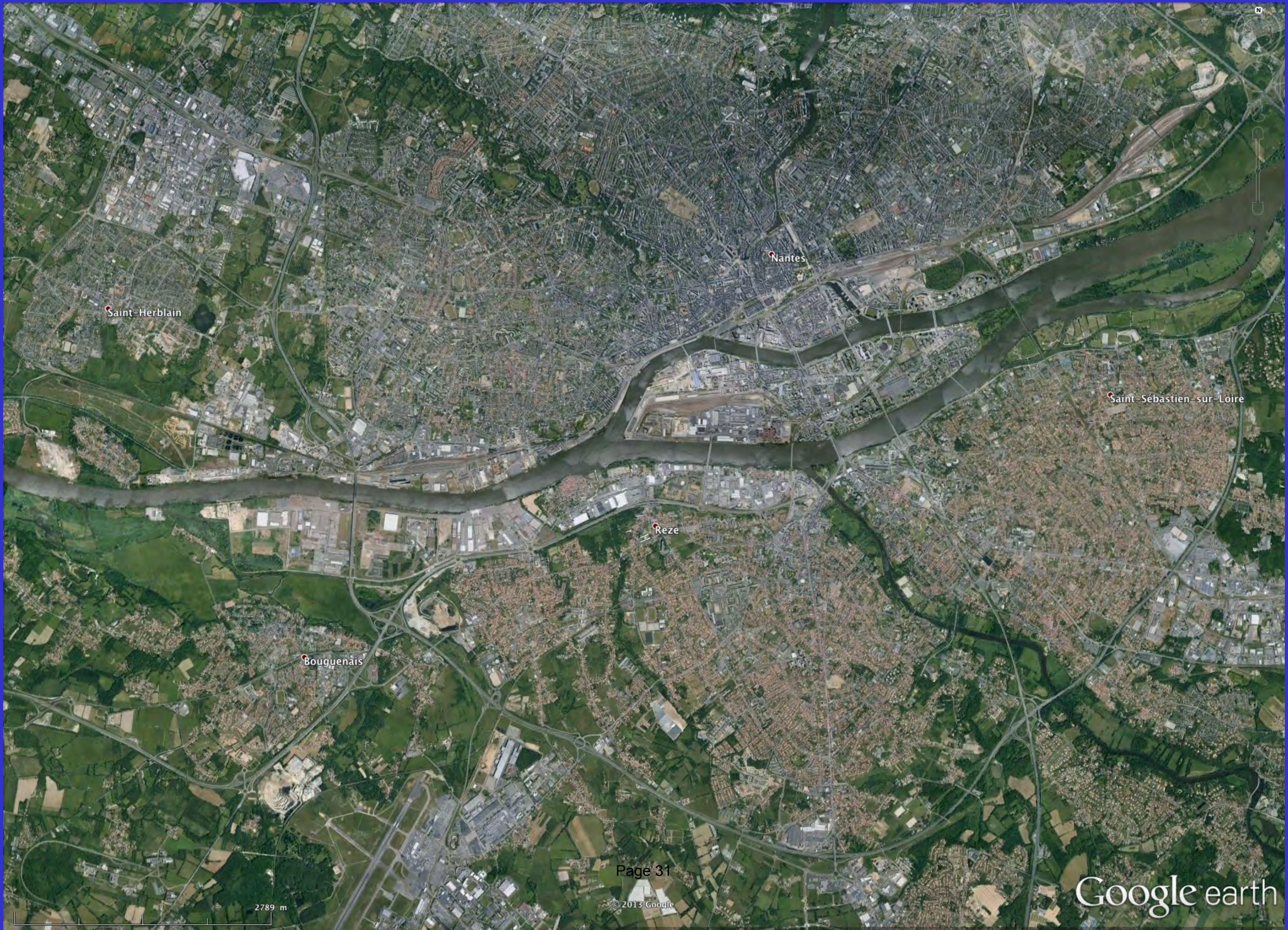

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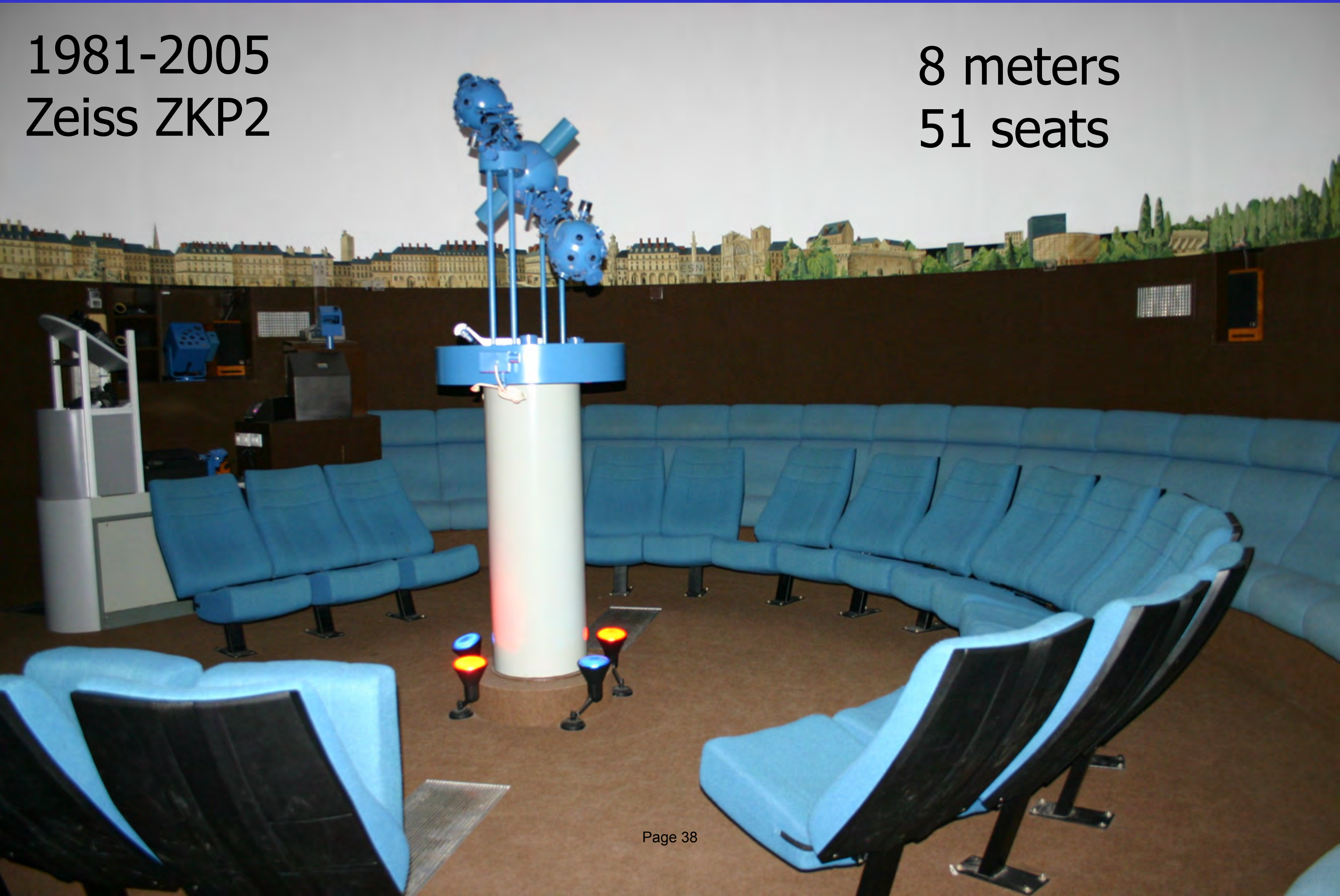

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Complete description of each planetarium

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- Building + Dome

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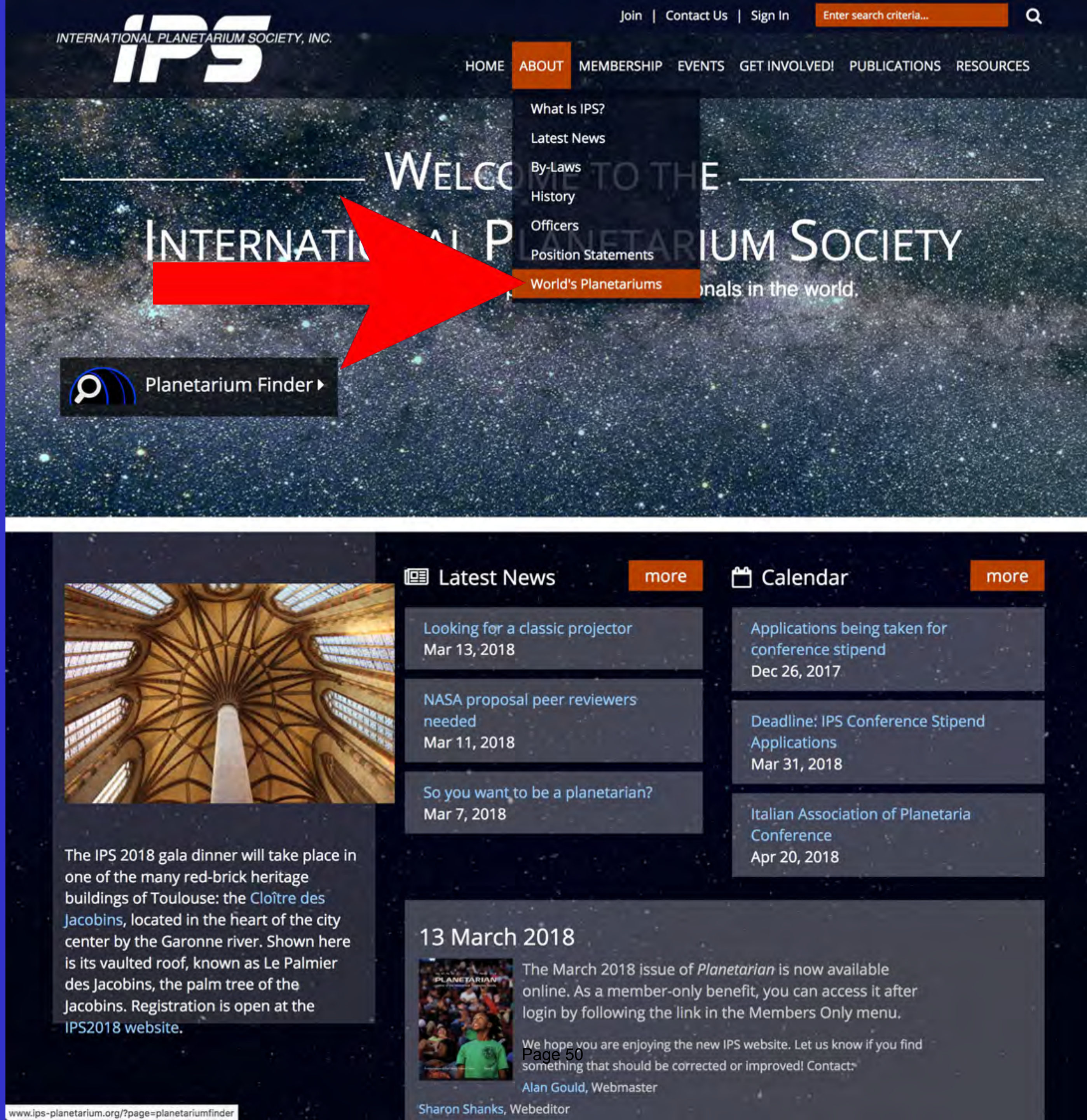

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Applications being taken for conference stipend
Dec 26, 2017
Deadline: IPS Conference Stipend Applications
Mar 31, 2018
Italian Association of Planetaria Conference
Apr 20, 2018
The IPS 2018 gala dinner will take place in one of the many red-brick heritage buildings of Toulouse: the Cloître des Jacobins, located in the heart of the city center by the Garonne river. Shown here is its vaulted roof, known as Le Palmier des Jacobins, the palm tree of the Jacobins. Registration is open at the IPS2018 website.
13 March 2018
PLANETARIAN
The March 2018 issue of Planetarian is now available online. As a member-only benefit, you can access it after login by following the link in the Members Only menu.
We hope you are enjoying the new IPS website. Let us know if you find something that should be corrected or improved! Contact:
Alan Gould, Webmaster
Sharon Shanks, Webeditor
www.ips-planetarium.org/?page=planetariumfinder

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PLANETARIUMS OF THE WORLD

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Pictured, from left: The FTD Digital Arena in Curitiba, Brazil; The Ole Romer Observatory, Aarhus, Denmark; The Novosibirsk Planetarium, Russia.

IPS Searchable Database of Planetariums (you will leave the IPS website)

Before July 2017, our *Directory of the World's Planetariums* consisted of a series of PDF documents that may still be found in the **Legacy IPS Directories** page.

You can update your listing here.

Here are some links to other planetarium-finding sites:

- **Planetariums in the World** (Interactive World Planetariums Database created by APLF—Association of French-Speaking Planetariums)
- Wikipedia's **List of Planetariums**
- Loch Ness Production's **Dome Theater Compendium**

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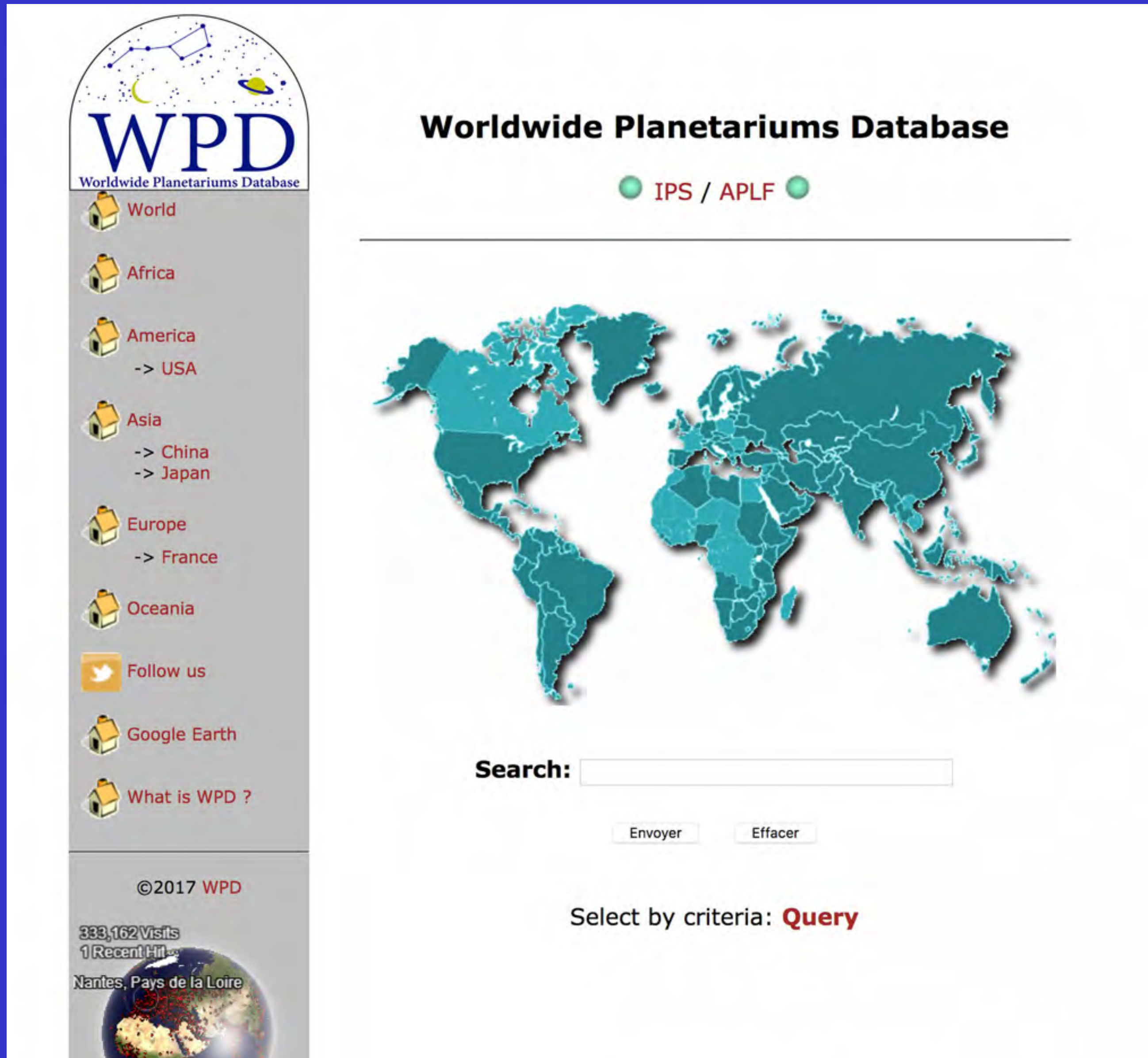

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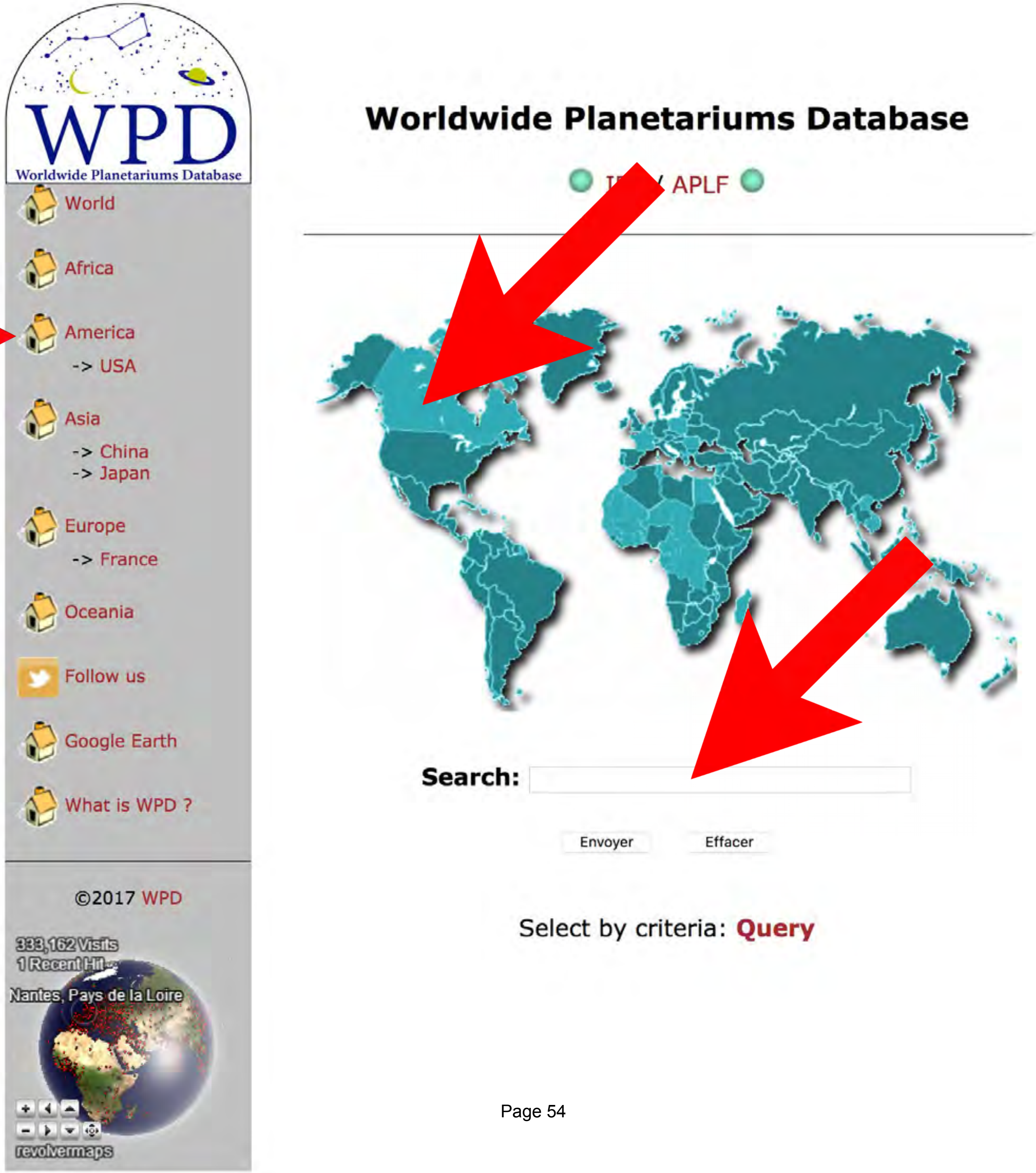
Exemple :

Search : EDMONTON Planetarium…

(IPS-2020 meeting)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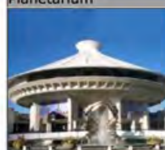
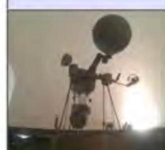
CANADA

ALBERTA

Planetarium	Address	Informations
	**Margaret Zeidler Star Theatre** 11211-142 street NW Edmonton AB T5M 4A1 http://www.edmontonscience.com info@twose.ca Phone: +1 780-451-3344 Fax: +1 780-455-5882	Opened in 1984 Dome of 23.0m 235 seats Digital system Sky-Skan Definiti
	**TELUS Spark** 220 St. George's Drive NE Calgary, T2P 5T2 http://www.sparkscience.ca/ info@sparkscience.ca Phone: +1 403-817-6800 Fax: +1 403-237-0186	Opened in 1967 Dome of 21.0m 245 seats Digital system Evans & Sutherland Digistar 5

BRITISH COLUMBIA

Planetarium	Address	Informations
	**The H.R. MacMillan Space Centre** 1100 Chestnut Street Vancouver, V6J 3J9 http://www.spacecentre.ca/ info@spacecentre.ca Phone: +1 604-738-7827 ext 249 Fax: +1 604-736-5665	Opened in 1968 Dome of 19.8m 230 seats Starball projector Zeiss UPP 23/7 (Harold) on lift Digital system SCISS Colorspace 4K
	**British Columbia Institute of Technology** 3700 Willingdon Avenue Burnaby B.C. V5G 3H2 http://commons.bcit.ca/planetarium/ geomatics@bcit.ca Phone: +1 604-451-7001	Opened in 1964 Dome of 9.1m 80 seats Starball projector Spitz A3PR Digital system Prototype Roundhouse Productions
	**Okanagan Science Centre** 2704 Hwy 6 Vernon, BC. Canada, V1T 5G5 http://www.okscience.ca/new-events/2017/7/20/pla info@okscience.ca Phone: +1 250-545-3644 Fax: +1 250-545-3644	Opened in ? Dome of 4.0m 30 seats Starball projector Learning Technologies Starlab
	**Canadian Planetariums** Vancouver http://www.canadianplanetariums.com/ info@CanadianPlanetariums.com Phone: +1 604-336-3821	Opened in ? Dome of 5.0m 30 seats Digital system Digitalis Education Digitarium

MANITOBA

Planetarium	Address	Informations
	**Manitoba Museum** 190 Rupert Avenue Winnipeg, MB R3B 0N2 https://manitobamuseum.ca/main/visit/planetarium info@manitobamuseum.ca Phone: +1 204-956-2830 Fax: +1 204-942-3679	Opened in 1968 Dome of 18.0m 287 seats Starball projector Zeiss Model Vs (Marvin) Digital system Evans & Sutherland Digistar

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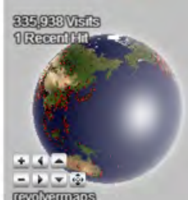


Margaret Zeidler Star Theatre
TELUS World of Science

EDMONTON - ALBERTA

Type: Museum

Address: 11211-142 street NW - Edmonton AB T5M 4A1
Country: CANADA

Latitude: 53°33'38" N - **Longitude:** 113°33'48" W - **Altitude:** 675m

Website: http://www.edmontonscience.com
Website 2: https://www.facebook.com/EdmontonScience
Email: info@twose.ca
Phone: +1 780-451-3344
Fax: +1 780-455-5882
Director, contact: Frank Florian, Alan Nursall (CEO)

Opened in 1984

Dome of 23.0m including 235 seats
Oriented No
Tilt No

Digital system Sky-Skan: Definiti
Software: DigitalSky Dark Matter
Video system Sony : VPL GTZ270 (x12)
Resolution 10.0 K

Other: IMax 3D (other theater)

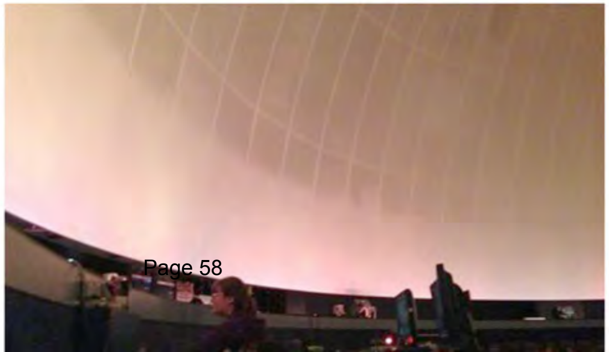
Dome: Astro-Tec Ulteria

Exhibit area: 1860m²

Observatory Yes
Gift Shop Yes
Lasershow Yes
Portable: 3 mobiles

History: 1960 until 1983: Queen Elizabeth II Planetarium: 7.3m/75s/Goto Venus (see 2871) - 1984 New buil[illegible]23m/220s/Zeiss ZGP - 2008: Fulldome (5+1 Goto F35) Sky-Skan
Sept. 5, 2017: closed for large renovations (Aurora project, CA$40 million) for 2020: Zeidler Dome Theater, 23m Ulteria/235s/Sky-Skan/10K (12 Sony GTZ270) $5.5 million - IPS2020

History: 1960 until 1983: Queen Elizabeth II Planetarium: 7.3m/75s/Goto Venus (see 2871) - 1984 New building: 23m/220s/Zeiss ZGP - 2008: Fulldome (5+1 Goto F35) Sky-Skan
Sept. 5, 2017: closed for large renovations (Aurora project, CA$40 million) for 2020: Zeidler Dome Theater, 23m Ulteria/235s/Sky-Skan/10K (12 Sony GTZ270) $5.5 million - IPS2020
Last major evolution: 2008: Digital



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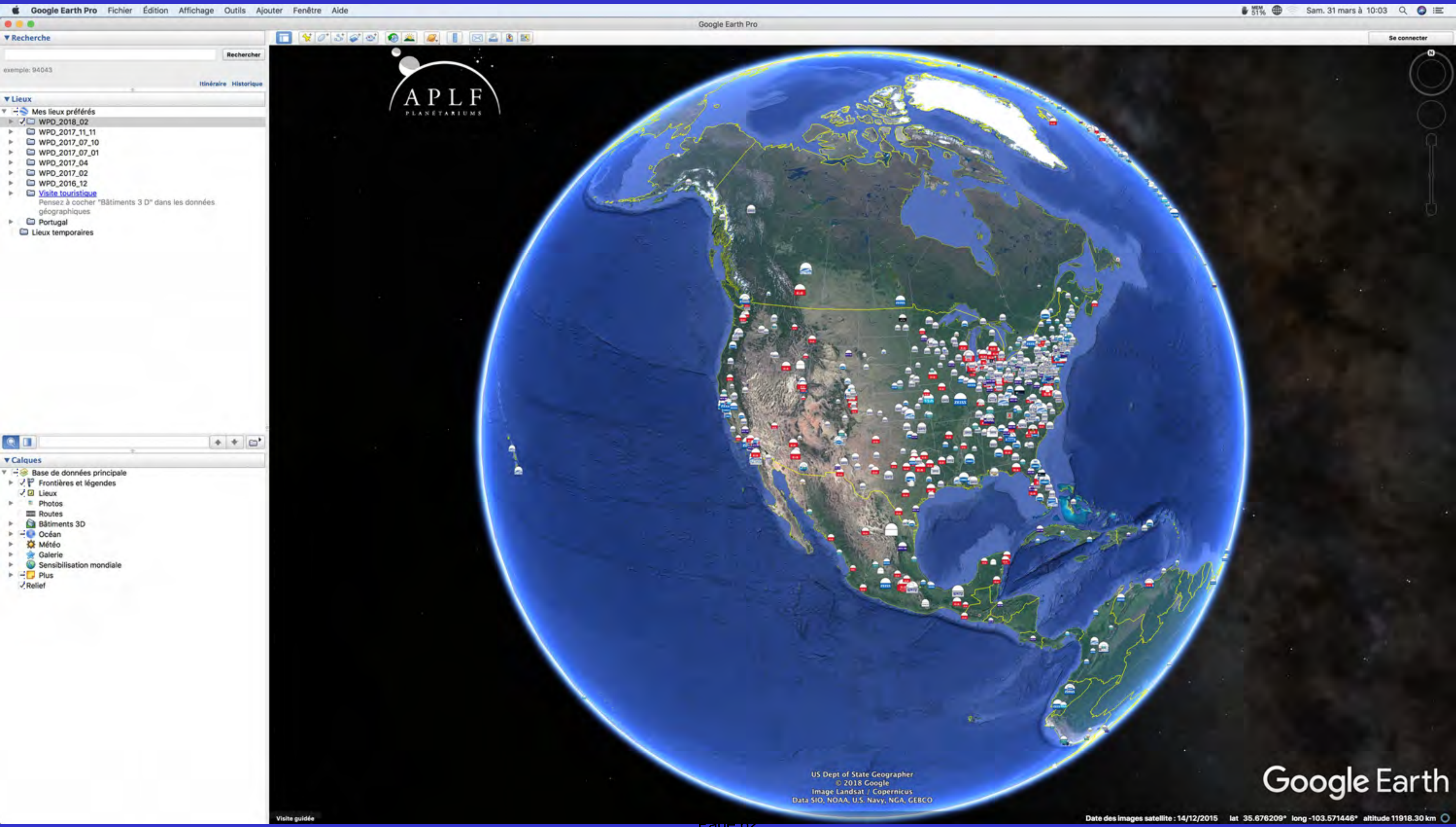

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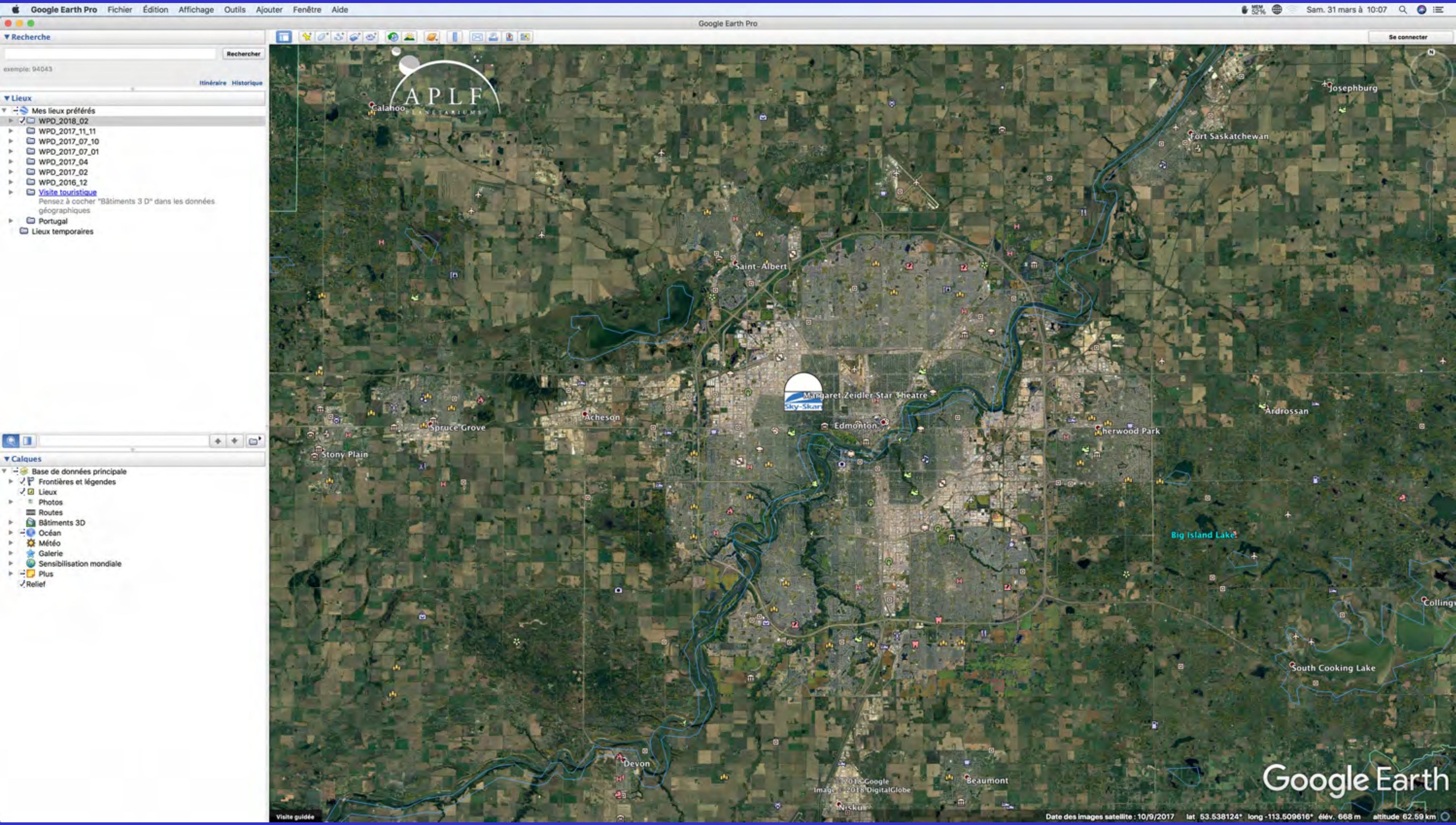

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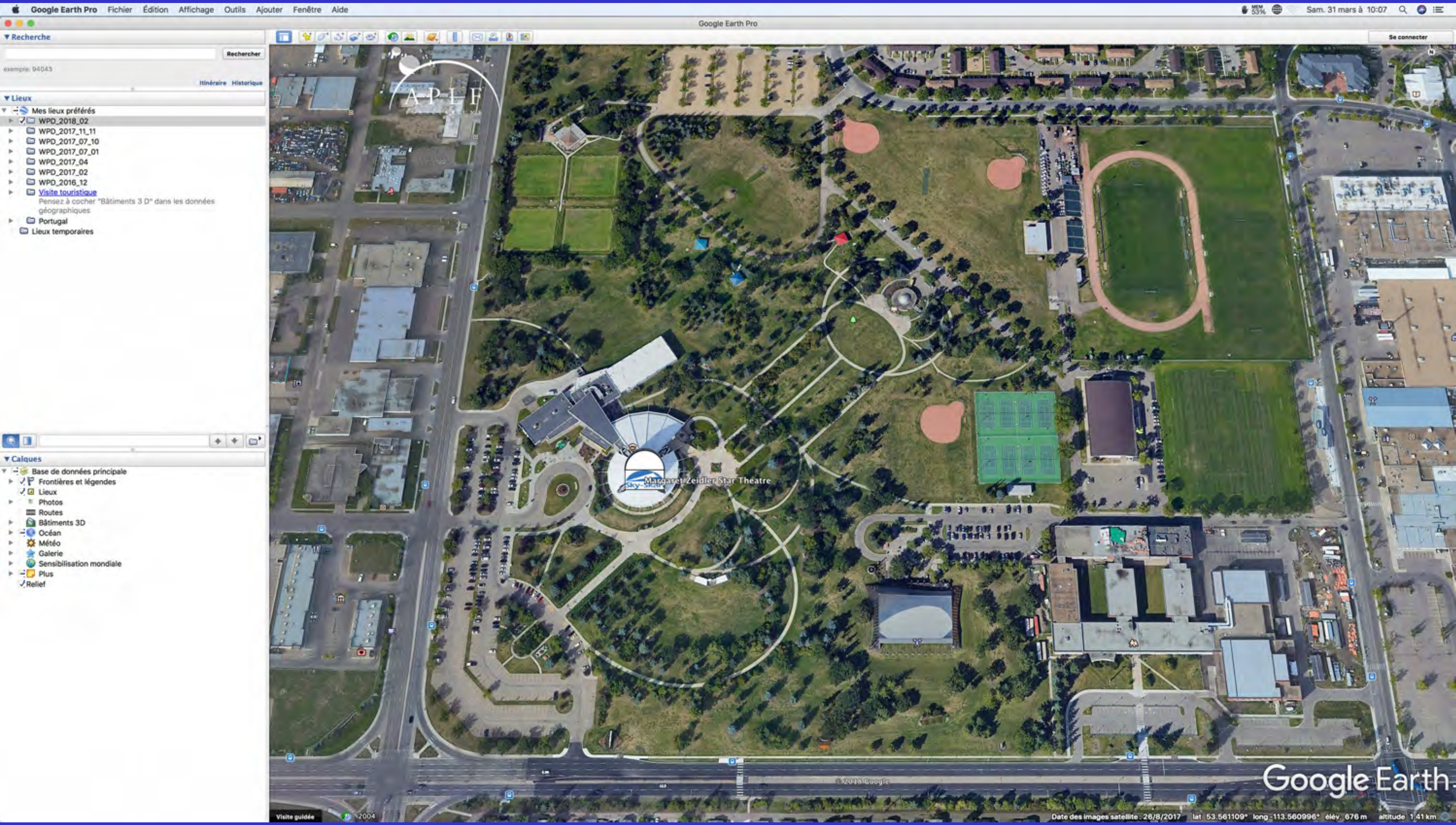

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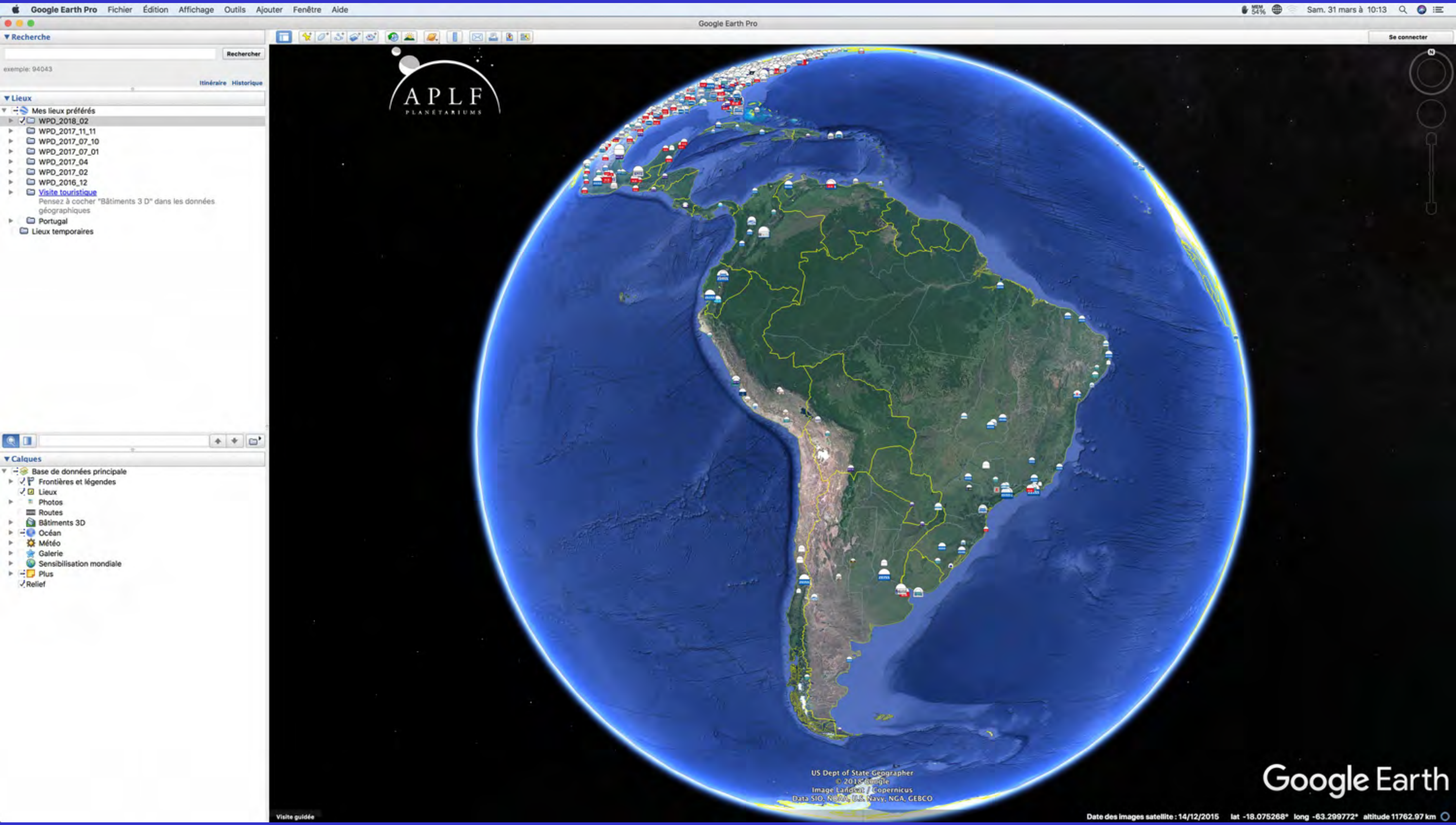

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QUERY the DATABASE

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Query on the planetariums database

Structure : ◯ Fixed ◯ Mobile

Status : ◉ Open ◯ Closed

Opened after: 1923 **Opened before:** 2025

Altitude greater than: 0 meters **Altitude lower than:** 8848 meters

Minimum Diameter: 0 meters **Maximum Diameter:** 50 meters

Minimum seats: 0 **Maximum seats:** 999

◯ Oriented ◯ Not oriented

◯ Tilted ◯ Not tilted

Builder : All Companies

System : ◯ Optomechanical ◯ Digital ◯ Hybrid

Video projector : All models

Minimum Resolution: 0 K **Maximum Resolution:** 16 K

Stereoscopy (3D) : ◯ Yes ◯ No

Continent : All continents

Country : All Countries

State : All States (USA)

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Worldwide Planetariums Database

WHAT'S NEW?

- Twitter (relayed on Facebook)

- Internal Search Engine

- Names (director or team)

- Closed planetariums (by Query)

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Listes 0
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FRANCE
aplf-planetariums.info/en/index.php
Inscrit en novembre 2012
255 Photos et vidéos
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Tweets & réponses
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Evans & Sutherland @ES_Digistar · 6 mars
El Paso's only planetarium to host free public event on Friday elpaso411.com/2018/02/el-pas… via @elpaso411
À l'origine en anglais
El Paso's only planetarium to host free public event...
Whether you're a young person or young at heart, The Gene Roddenberry Planetarium is a place where everyone in El Paso can learn about our Universe and
elpaso411.com
1
2
Vous avez retweeté
Evans & Sutherland @ES_Digistar · 5 mars
The beautiful Swami Vivekananda Planetarium in Pilikula, India, officially opened March 2nd to much fan fare and excitement! Congratulations to all! #DIGISTAR #THEDIFFERENCEISDIGISTAR #DIGISTARFAMILY
À l'origine en anglais
2
WPD @AUDEONdaniel · 5 mars
24 #planetariums in Virginia (USA) + 1 "portable"
aplf-planetariums.info/en/index.php?o…
Suggestions · Actualiser · Tout afficher
Clark Planetarium @SSU…
Suivre
FULLDOME OnDemand …
Suivre
FullDome Video @Fulldo…
Suivre
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Tendances pour vous · Modifier
#FemmesDeDemain
Engagez-vous avec Dove pour les #FemmesDeDemain
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#8mars
@nantesfr tweete à ce propos
#PSGRMA
45,4 k Tweets
#TOTJUV
63,4 k Tweets
#PSLeDebat
14,6 k Tweets
#JourneeDeLaFemme
2 362 Tweets
#naistenpäivä
1 750 Tweets
#IWD18
5 437 Tweets
#Weltfrauentag
3 259 Tweets
#JournéeDesDroitsDesFemmes
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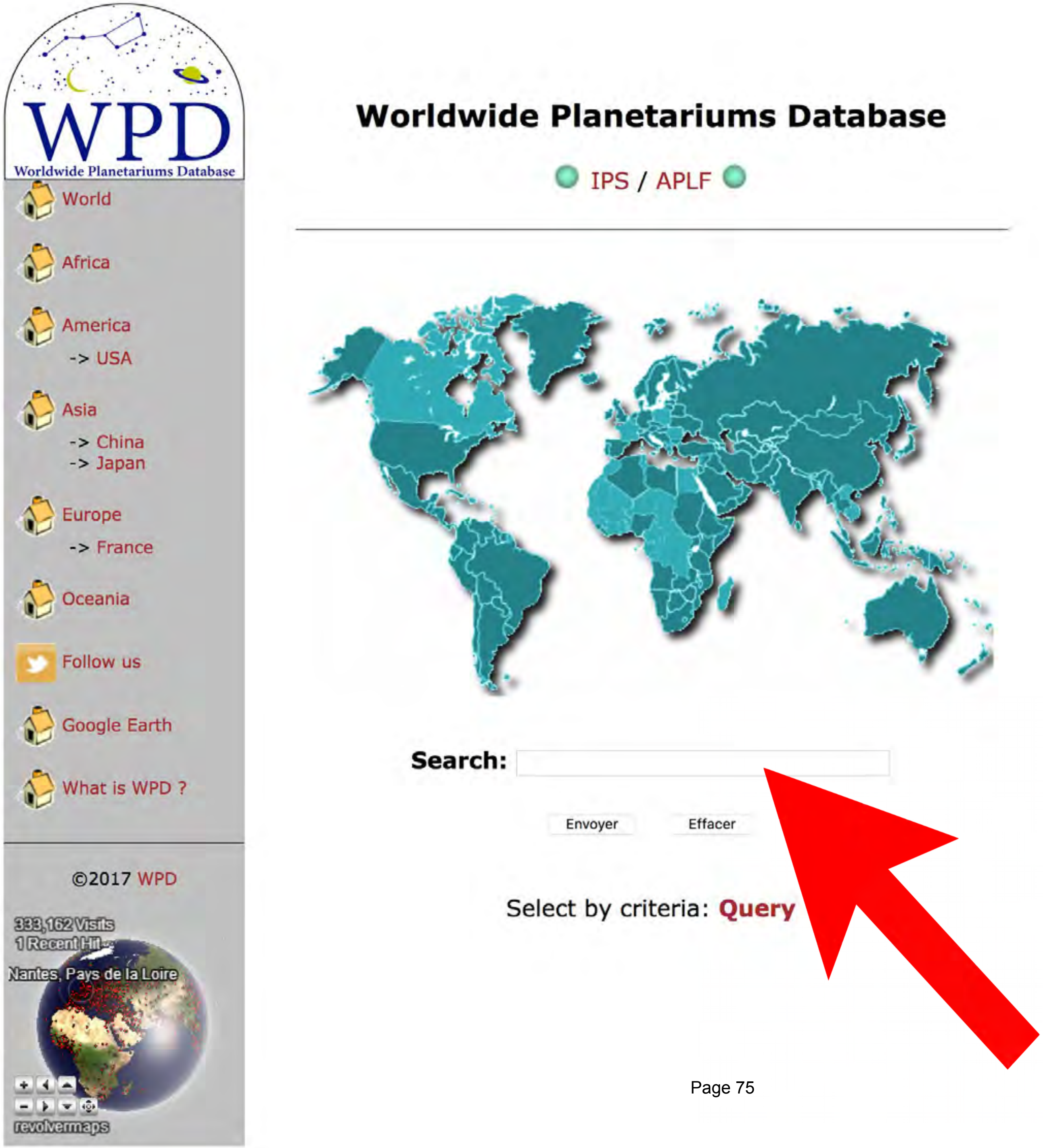
Internal Search Engine



Search by letters :

- Name planetarium
- Name staff (team)
- City

Worldwide Planetariums Database

STATISTICS

Total: 3000

Countries: 102

Fixed open: 2400

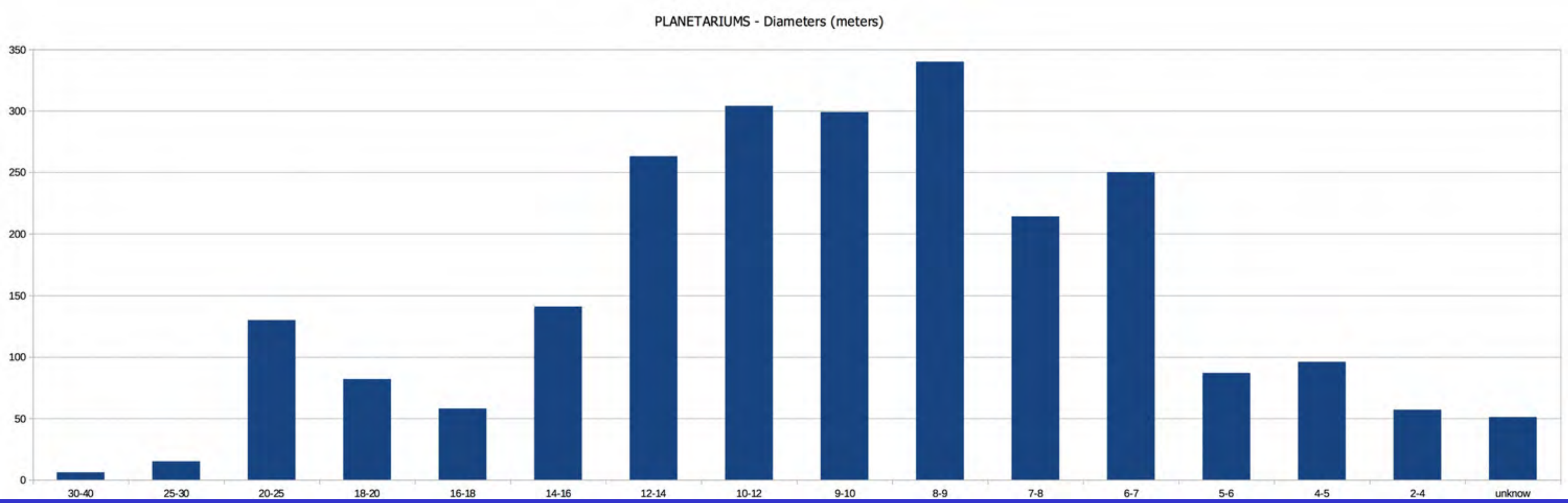
Portable: 200

Closed: 410

Worldwide Planetariums Database

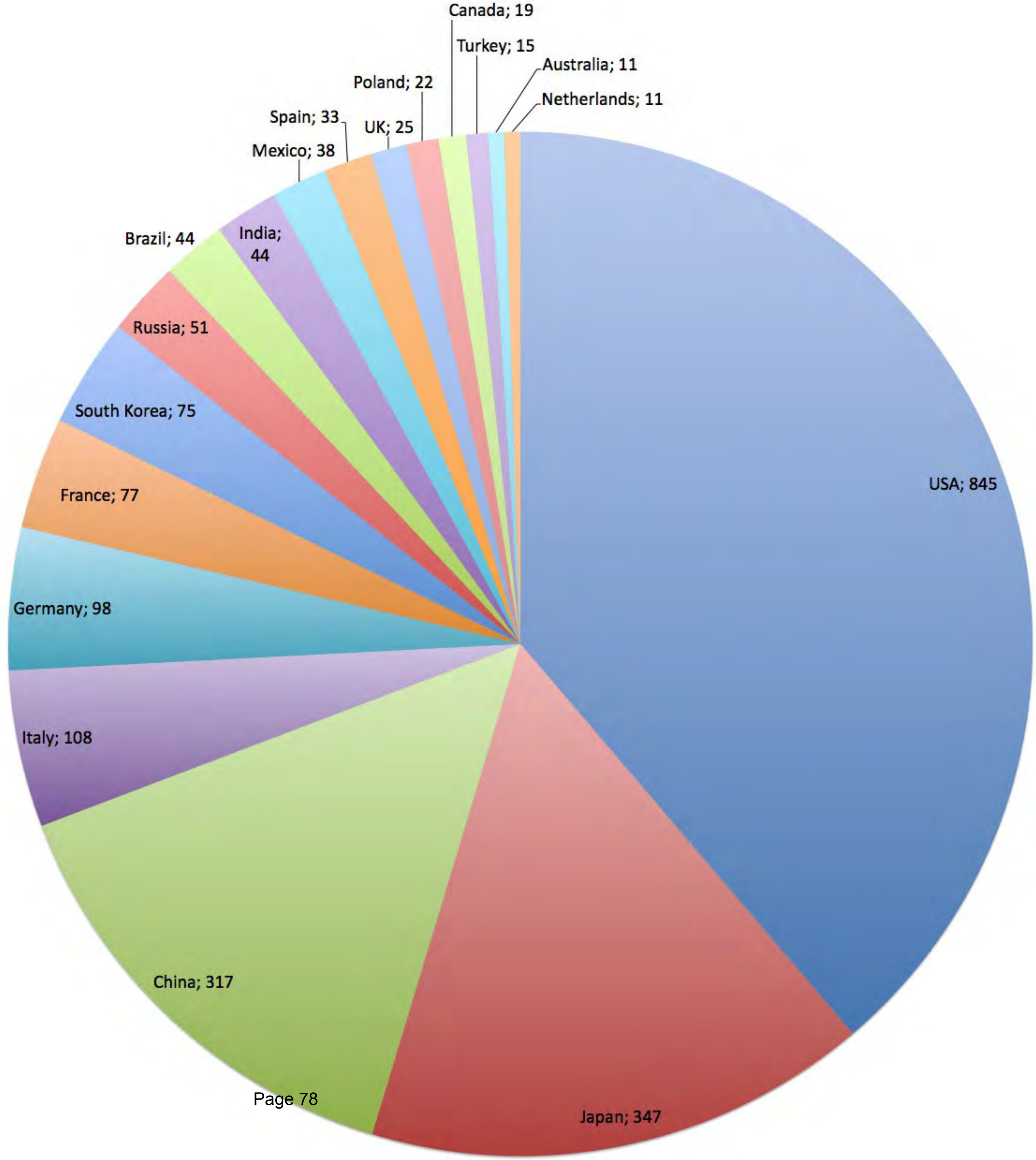
By diameters

2400 fixed planetariums



By countries

2400 fixed planetariums



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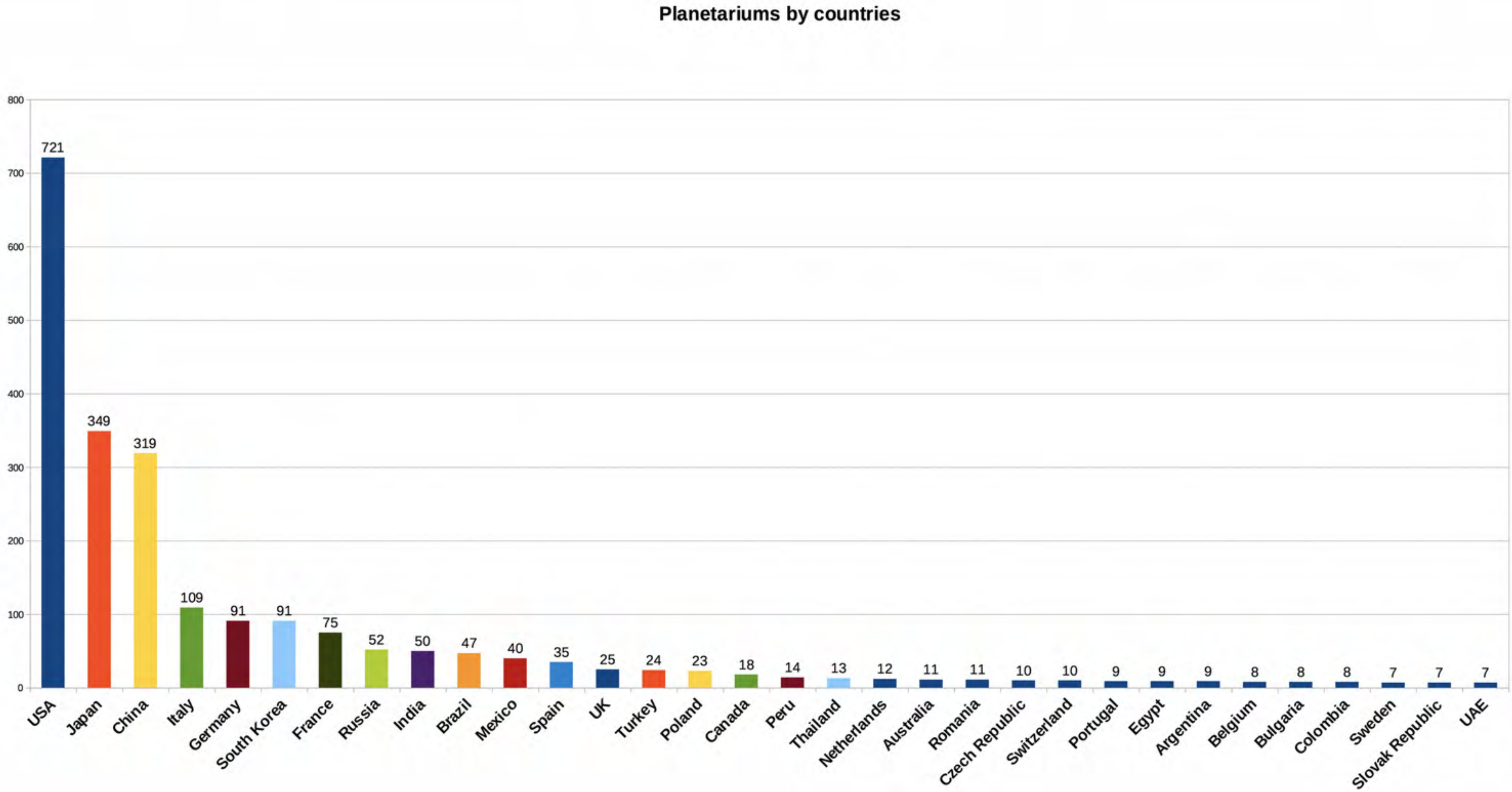
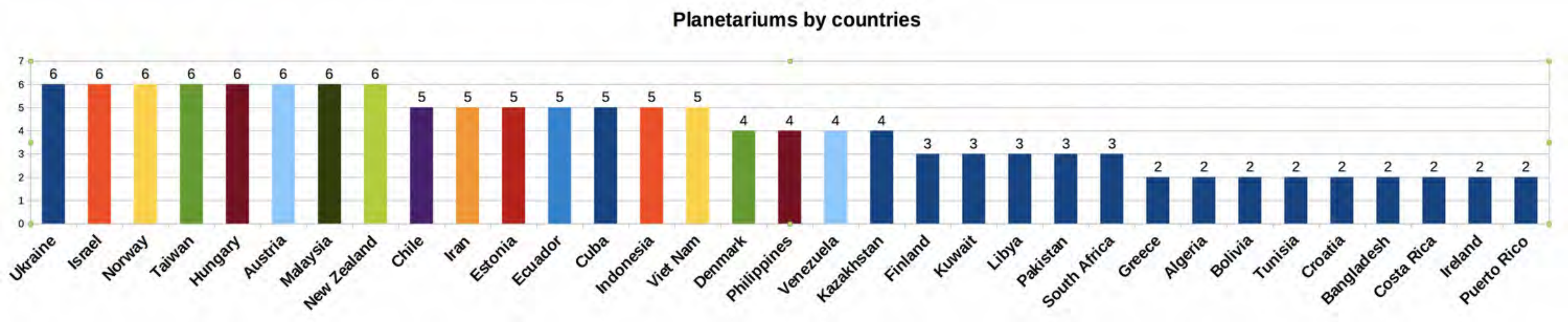
By countries

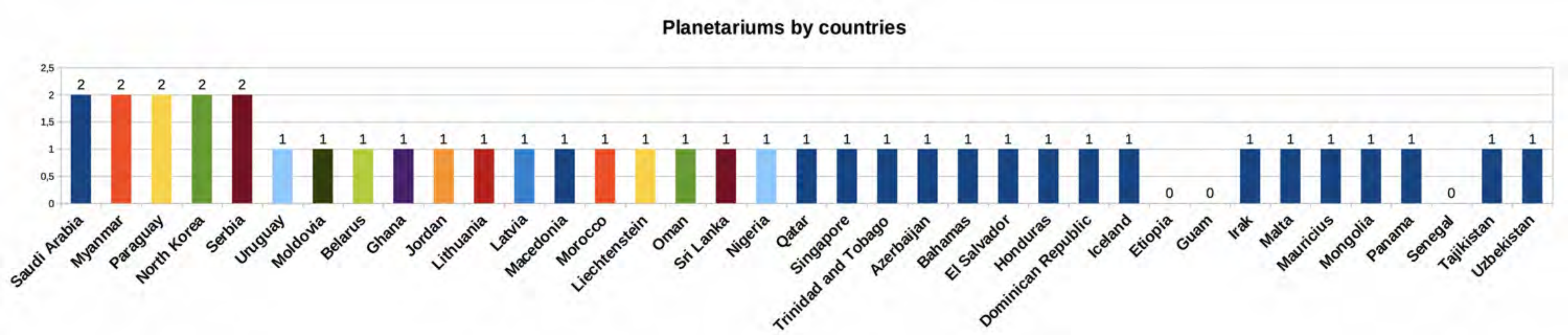
2400 fixed planetariums



By countries

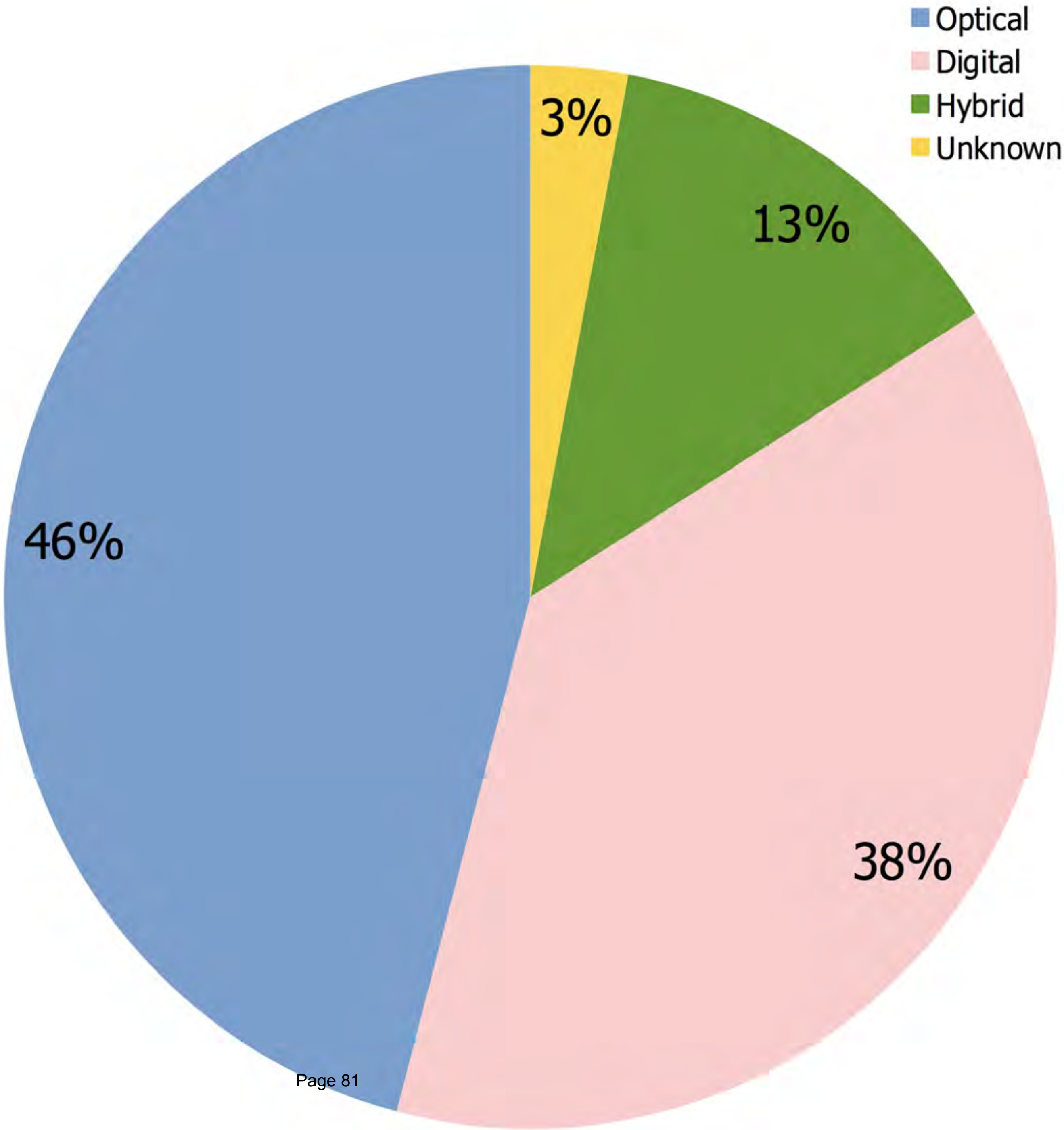
2400 fixed planetariums





Optical or Digital

2400 fixed planetariums



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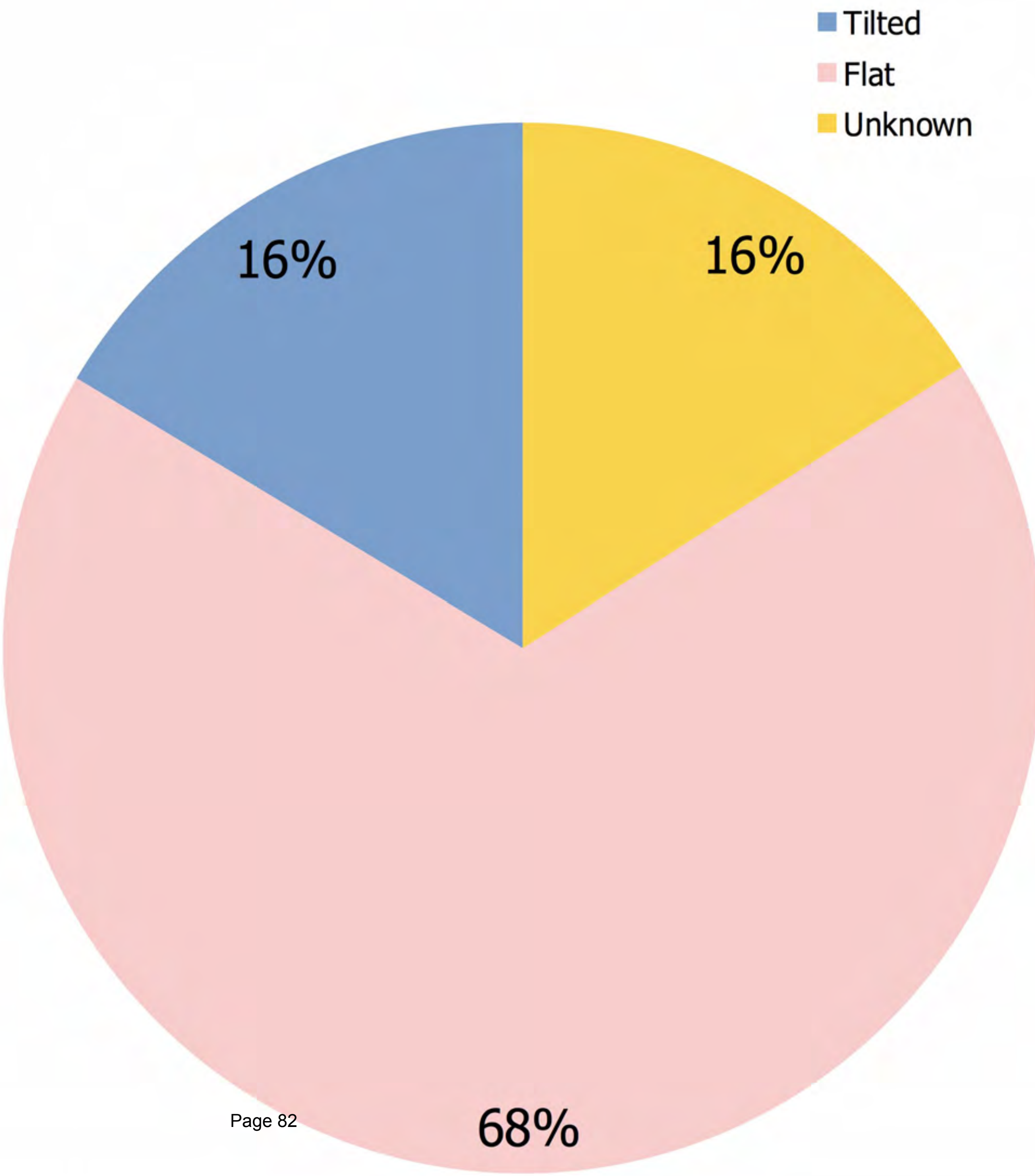
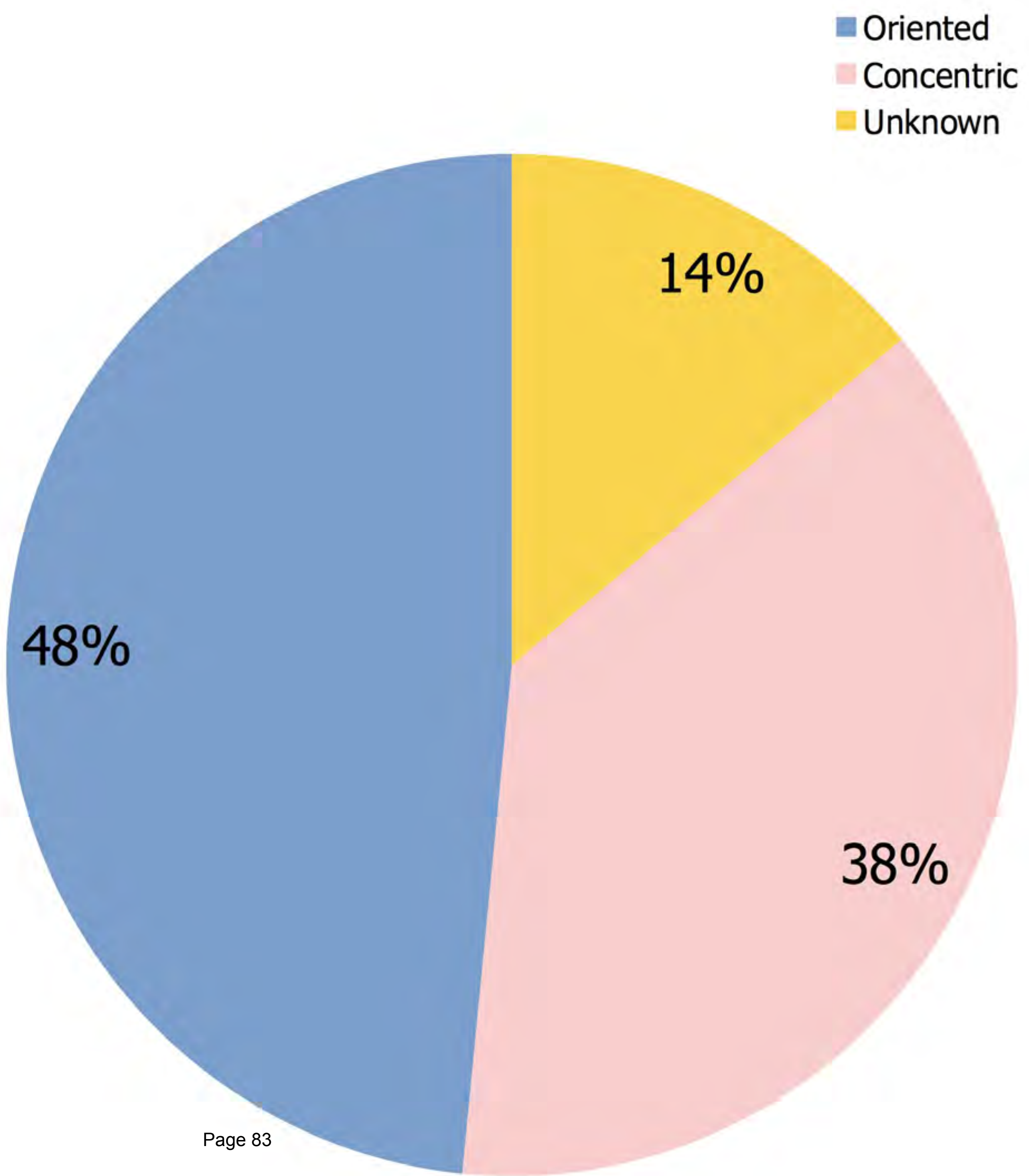
Flat or Tilted
(floor)

2400 fixed planetariums



Oriented or concentric

2400 fixed planetariums



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IPS 2018
Toulouse - France

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Daniel AUDEON
Nantes' Planetarium

www.aplf-planetariums.org/en/

Make your Planetarium accessible to the hearing impaired with connected eyewear

Christelle Barclay, Cyril Birnbaum
Cité des sciences et de l'industrie/Planetarium
christellebarclay@universcience.fr; cyrilbirnbaum@universcience.fr
Thierry Jori
thierry.jori@universcience.fr
Cité des sciences et de l'industrie/ R&D

BIOGRAPHIES

Cyril Birnbaum is the head of the Planetarium of *La Cité des sciences et de l'industrie* in Paris, France
Christelle Barclay is in charge of production and partnerships
Thierry Jori is in charge of R&D on this project

ABSTRACT

Until now, the shows screened in our Planetarium were barely accessible to the deaf and the hearing impaired. Having an interpreter in the theater or including subtitles are not relevant solutions if we want to preserve the immersive impression.
La Cité des sciences et de l'industrie's team (Accessibility Department, R&D, Planetarium's team) has been working for one year on state-of-the-art augmented-reality glasses. Thanks to this technology, the viewer can freely move his head to look at any part of the dome while having a translation dedicated to him.

I. CONNECTED GLASSES FOR THE HEARING IMPAIRED

I.1 The prototype

The newly upgraded Planetarium of *La Cité des sciences et de l'industrie* provides an HD 8K resolution. To make our theater accessible to the hearing impaired, we wanted an embedded technology that allows having a translation while preserving the immersive impression.

We decided to use the technology of connected eyeglasses based on the principle of augmented reality (popularized by Google glasses). Last year, we contacted the R&D Department of our museum to work on connected glasses. A first prototype with manual activation was tested thanks to the participation of our deaf colleagues from the accessibility Department.

The device is a connected eyewear storing video sequences with subtitles and an interpreter who is signing. This device was presented at the planetarium conference in Saint-Louis last October. The feedback encouraged us to continue to develop this device.

Figure 1 - Connected glasses-Epson

The model used is Epson's. Indeed, it works with the OLED projection technology. Unlike the LCD technology, it allows very deep black lays and therefore very transparent, which is necessary for the dark images screened in planetariums.

I.2 The finalized device

As he’s wearing the glasses, the viewer can see any part of the dome without losing the immersive impression. The projection onto the glasses is not visible by the other visitors next to him. In other words, you don’t need to plan a specific session. It’s a very cost effective solution.

Figure 2 - Connected eyewear in Planetariums

The control pad device allows the viewer, to choose the display: subtitles or translation into sign language.

The other important thing is the synchronization of the translation with the show. It is made possible by interfacing the application with the broadcasting system.

II. CONNECTED GLASSES IN YOUR PLANETARIUM, WHY NOT?

II.1 Automatic activation

Simple! To store videos in the glasses, the technician only has to plug the control pad as (s)he can do when (s)he transfers files from his (her) USB drive or his (her) mobile phone

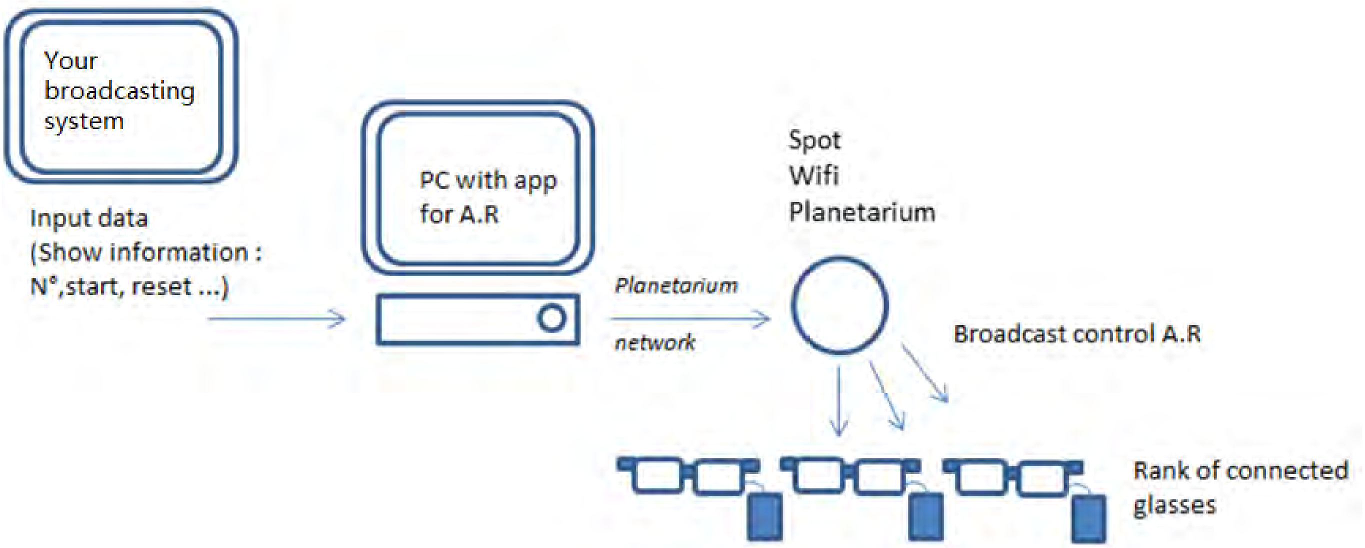

Figure 3 - How does it work?

The activation is automatic thanks to the interfacing with the broadcasting system. This is the same procedure used for audioguides.

We need a computer dedicated to the application which receives the information about the show. Then, the application sends all information into the glasses thanks to the WiFi in the theater.

Our application is designed for interfacing with the RSA system but there are no technical difficulties to adapt it for another supplier.

II.2 Shows available in your Planetarium

From September, the shows “Night lights” and “the Moon” will be available with video including English subtitles.
We can assist you to meet your planetarium’s needs.

If you wish having further information, please feel free to contact us.

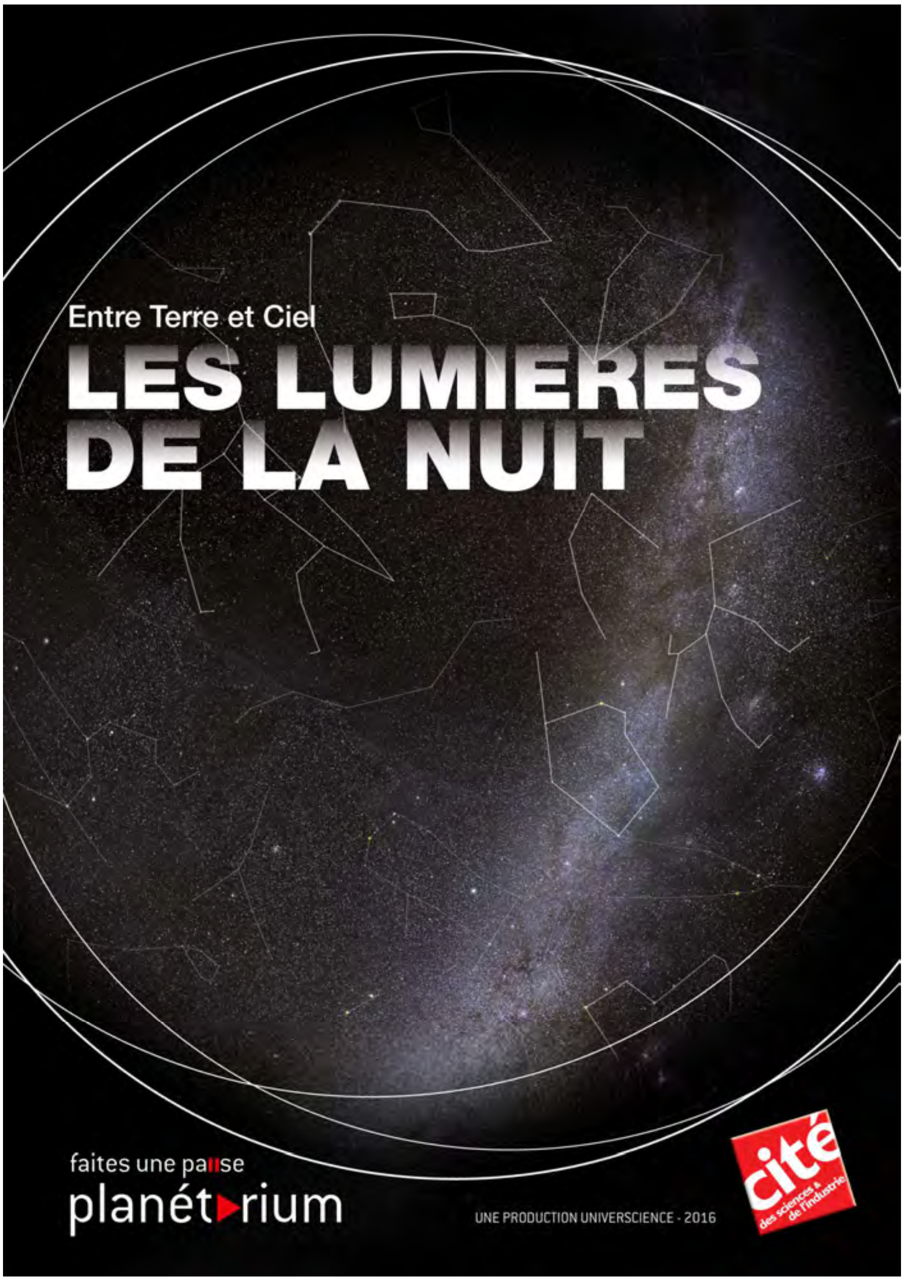

Figure 4 - "Night lights", a show available for the hearing impaired

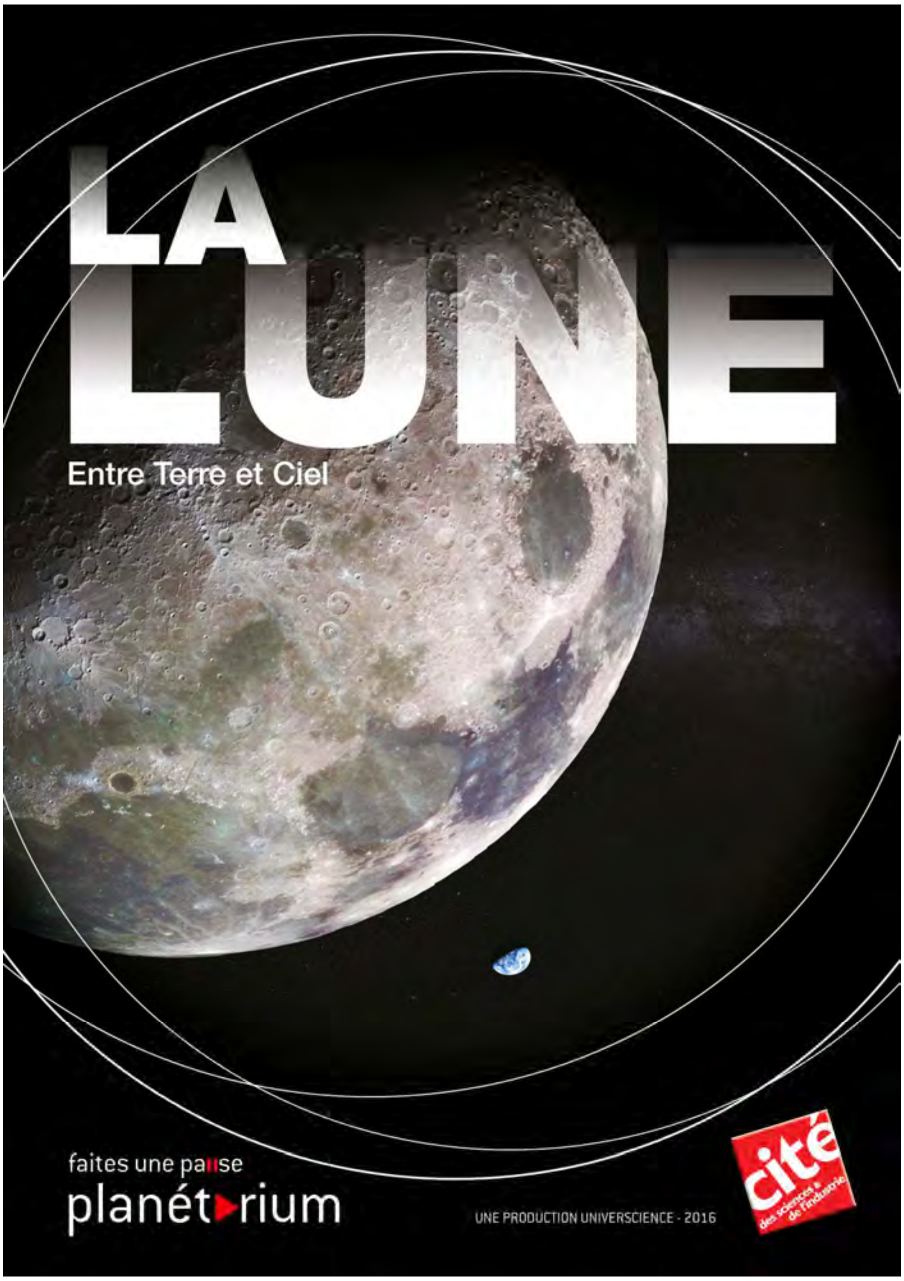

Figure 5 - "The Moon", a show available for the hearing impaired

ACKNOWLEDGMENTS

RSA Cosmos experienced staff assisted us in this project, especially in the interfacing between the application and the broadcasting system.

Epson France facilitated our testing and survey by lending glasses.

REFERENCES

An Allocentrist Approach to Teaching the Phases of the Moon in a Digital Full-dome Planetarium

A.Bélanger Simon, Chastenay Pierre, Riopel Martin, *UQAM*
Email: a_belanger.simon@courrier.uqam.ca

ABSTRACT

This research aims to identify what elements of an allocentric digital full-dome planetarium session are important for 5th and 6th graders (10-12 years old) to help them better understand Moon's phases. Qualitative data will be obtained through semi-structured group discussions following the presentation of an allocentric session about the phases of the Moon at the Montreal Planetarium. Quantitative data will be gathered before and after the session using a multiple-choice questionnaire about different aspects of the phases of the Moon. Preliminary results shows that an allocentric digital full-dome planetarium session about the lunar phases needs to present eclipses as well. It also needs to have sound effect to simulate the sound of rocket boost while navigating through space. The allocentric point of view and the feeling to be in a spacecraft in space was well received and showed interesting results on understanding the lunar phases.

INTRODUCTION

The teaching of the phases of the Moon in a traditional school setting has many shortcomings: the Moon is often invisible during normal school hours, bad weather can hinder observations, the change from one phase to the next is slow, etc. What's more, research has shown that the experience of looking at the Moon from a geocentric point of view is often the source of the most common misconceptions, like the idea that phases are caused by clouds blocking our view, or the shadow of the Earth projected on the Moon (Bakas et Mikropoulos, 2003; Black, 2005; Cole *et al.*, 2015). Among many possible solutions to these problems, the visit to a planetarium has proved several times its usefulness for learning astronomical concepts (Brazell et Espinoza, 2009; Mikropoulos et Natsis, 2011). In recent years, new technologies have revolutionized the traditional planetariums. The introduction of video projectors and high-performance computers has transformed the planetarium theater into a spaceship that allows visitors to see and experience a different point of view than geocentrism on highly spatial and dynamic systems, like the Sun-Earth-Moon. While several studies in the past have concentrated on the pedagogical practices to be used in a traditional planetarium, none to our knowledge has been interested in the elements of an allocentric session under a planetarium dome that promotes a better understanding of a complex astronomical phenomenon like the lunar phases (Slater et Tatge, 2017). This research aims to explore the new capabilities offered by digital planetariums. We will attempt to develop guidelines and procedures for conducting educational sessions in such planetariums. To do this, we will perform a session about the phases of the Moon in a digital planetarium using design experiment. At the end of each implementation of the session, we will collect data that will allow us to improve it and to build our knowledge on this new learning tool that is the digital planetarium.

I. THE PLANETARIUM

I.1 Traditional

Since their appearance in the mid-1920s until the beginning of the 21st century, so-called traditional planetariums have not undergone any notable change (Chartrand III, 1973, Marché II, 1999, 2001). These are immersive environments that can simulate various movements of the celestial vault. They do it thanks to two fundamental elements: the star projector and the dome shape of the theater. The theater of a planetarium is a circular room surmounted by a dome-shaped ceiling that serves as a screen. In the center of this room, there is an optomechanical instrument known as a star projector. This projector reproduces the starry sky on the ceiling of the room. With the addition of other specialized projectors, it is also possible to project objects like the Moon, the planets and the Milky Way. This projection capability combined with the form of the theater allows the entire field of view of the visitor to be occupied and thus contributes to immersion and presence. In addition, the projection devices of a planetarium can move the stars in the sky faster than the regular passage of time. Thus, a visitor can observe a complete lunar cycle in just minutes rather than 28 days. He could also witness the movement of the Sun in the sky during the year (analemma), a phenomenon difficult to observe due to its temporal length.

I.2 Digital

With the new digital technologies of the first decade of the 21st century, planetariums are experiencing a real revolution. The new projectors and increasingly powerful computers allow the construction of digital planetariums. From an architectural point of view, a digital planetarium is very similar to a traditional planetarium. Both are immersive virtual reality environments with a domed ceiling that acts as a screen. Some digital planetariums have an optomechanical star projector in the center while others do not. However, the big difference between the two types of planetarium, traditional and digital, lies in their ability to project images. Digital planetariums are equipped with high quality video projectors that have the ability to fill the screen, and thus the visual field of the viewer, with computer-generated imagery, videos and realistic representations. This digital projection capability is made possible by video projectors, of course, but also by computers. These computers include modern space mapping software, extremely powerful graphics cards, and numerous databases. These systems, coupled with video projectors, allow to present the starry sky, the solar system, the galaxy, etc. with great precision and based on the latest scientific data. The planetarium thus becomes, for the visitor, a true spaceship, allowing him to navigate through space and to explore different points of view. The visitor can discover the Universe with a look that is different from the traditional geocentric point of view. These new allocentric points of view make it possible to revisit common astronomical phenomena, like the lunar phases, in order to explain them adequately, without the biases and limitations of geocentrism and, possibly, to change the alternative conceptions of viewers (Chastenay, 2015). Like traditional planetariums, digital planetariums have shown their effectiveness in teaching astronomical concepts (Carsten-Conner *et al.*, 2015; Chastenay, 2015; Yu *et al.*, 2015; Zimmerman *et al.*, 2014).

II. PREVIOUS RESEARCH

In order to realize a session allowing the learning of an astronomical concept in a planetarium, many studies have been interested in the different elements which contribute to it.

Mallon (1974) demonstrated the importance of the physical presence of a communicator in a planetarium. In his study, he presented two planetarium programs identical to 2nd grader students, one with a live communicator and the other with a pre-recorded narrative tape. Students who attended the session with a facilitator performed better on the post-test than the second group.

In his studies, Ridky (1974) focused on public reception in a planetarium. Using two identical programs with 8th grader students, he showed that students who received an orientation session (presentation of the architecture of the room and its equipment) before the presentation of the program had a better retention of the information and performed better at the post-test. Ridky titled "demystification of the planetarium" this orientation session where we present the projectors, the dome-shaped screen, the operation of the star projector, etc. In the same way, Bisard (1979) demonstrated the importance of a welcome note summarizing the upcoming session, whether done by a live presenter, pre-recorded, or simply projected on the screen.

With regard to the sound and musical plot of a session in a planetarium, Wooten (1979) compared two groups of viewers who attended a live performance, one with a musical score and the other without. His study showed that the musical framework can sometimes interfere with understanding when it is not well synchronized with the visual elements. Note however that when the score is well synchronized with the show, the results are different. Brunello (1992) discovered a positive effect on learning. The music and soundtrack come at best to enhance the experience, but can also be the source of distractions that undermine learning.

It is also noted that the success of the planetarium lies in its visual impact and it should focus on this aspect (Gutsch, 1978). Based on the visual success of the planetarium, Hunt (1991) has shown that it is important for viewers to have time to appropriate visual information. Moreover, in certain situations where there is a lot of information to be processed, it is relevant to orient the visitor, using a pointer, arrows, etc., towards certain important elements (Hunt, 1991).

Several researchers (Bakas et Mikropoulos, 2003; Fletcher, 1977; Friedman *et al.*, 1976; Mergler, 1975; Schafer, 1977) were interested in the form of the scenario that should be adopted by a learning session in a planetarium. They compared participatory approaches (ask & do) and more traditional approaches (show & tell). In the majority of research (Fletcher, 1977; Friedman *et al.*, 1976; Mergler, 1975; Schafer, 1977), an approach based on public participation was more appreciated by the audience and gave better results in terms of learning. However, there are some precautions to take. In their research, Bakas et Mikropoulos (2003) studied the learning of various astronomical concepts (the movement of the Earth and the Sun, the day-night cycle and the seasons) with 102 high school students in a virtual environment. Their conclusion is that it is better to accompany students in their navigation than to let them go freely.

In short, the learning sessions within a traditional planetarium should be presented live by a communicator in the room. It should begin by presenting the theater and its accessories as well as the program of the session. The session will have to give a measured place to the musical frame and focus on visual information, while drawing the spectators' eyes towards the most important elements. In addition, the moderator and session designers should coordinate to provide spectators with an immersive and interactive experience.

The researches mentioned above were conducted using traditional planetariums, but what about digital planetariums? With the new perspectives offered by these planetariums, what do we know about the elements that an allocentric session in a digital planetarium should adopt to promote the learning of an astronomical concept? We have no reason to believe that the elements noted in the traditional planetariums could not be used during such a session, but perhaps other elements, related exclusively to the allocentric point of view, are important. To our knowledge, no research has yet addressed this issue (Slater et Tatge, 2017).

III. THEORETICAL FRAMEWORK

In science education, it is generally accepted that students learn by interpreting the nature of things around them based on their experiences. Thus, the learner will build personal theories based on his observations, past experiences, values, etc. (Chastenay, 2013). At the age of 10-12, learners have few experiences and knowledge to guide them and therefore the primary theories they develop are often at odds with accepted scientific theories (Kücüközer *et al.*, 2009; Vosniadou, 1991). These primary theories are called misconceptions and despite the fact that they do not fit scientific theories, they make a lot of sense for children (Kücüközer *et al.*, 2009). Misconceptions therefore hinder learning and this is especially true in the case of the lunar phases (Kücüközer *et al.*, 2009; Palmer, 2007; Vosniadou, 1994). Instead of just passing on information, teachers should consider the students' conceptions in order to provoke a real conceptual change.

In the case of teaching the phases of the Moon, constructivism is particularly interesting since it has been proven to be well equipped to address misconceptions (Kavanagh *et al.*, 2005; Lelliott et Rollnick, 2010; Mills *et al.*, 2016). Lunar phases are an abstract astronomical concept. In order to fully understand it, one must be able to mentally construct a three-dimensional interacting system with the Earth, Sun and Moon (Chastenay, 2015; Cole *et al.*, 2015; Kavanagh *et al.*, 2005; Vosniadou, 1994). However, our strictly geocentric point of view and the difficulty we have in representing the sizes and distances of astronomical objects contributes to limit this mental construction (Black, 2005; Chastenay, 2015). This difficulty contributes to a profusion of misconceptions about lunar phases from students, the most common ones being that the phases of the moon are created by Earth's shadow or by clouds passing in front of the Moon (Bell et Trundle, 2008; Chastenay, 2013; Kavanagh *et al.*, 2005; Kücüközer *et al.*, 2009; Liu, 2005; Vosniadou, 1994). A traditional teaching approach, based on textbooks for example, does not bring about any real conceptual change in the student (Kücüközer *et al.*, 2009). On the contrary, it could even have contributed to creating and reinforcing some of the most common misconceptions (Chastenay, 2013; Kücüközer *et al.*, 2009).

Learning can be seen as "*the result of the interaction between what the student is taught and his current ideas or concept.*"(Posner *et al.*, 1982). So, when the student is faced with observations that challenge his personal theory, we can encourage him to use a new model. To make this conceptual change, the new model must be intelligible, plausible and fruitful (Posner *et al.*, 1982). This mechanism of conceptual change will be the basis of our teaching strategy.

The most popular misconceptions about the lunar phases are the result of a multitude of misconceptions about the Earth, Moon, and Sun. Among these are the Earth-Moon distance which is often underestimated, the Earth and the Moon imagined as two-dimensional circles instead of spheres, and the light of the Moon which is sometimes believed to be emanating from the Moon itself instead of being the reflected light from the Sun (Chastenay, 2013; Comins, 1999; Kücüközer *et al.*, 2009; Vosniadou et Brewer, 1992; Vosniadou et Brewer, 1994). To fully understand the phenomenon of the phases of the Moon, one must be able to understand the place of the Earth in relation to the Moon and the Sun as well as the movements of these celestial objects (Barnett et Morran, 2002; Chastenay, 2015; Cole *et al.*, 2015; Vosniadou, 1991). He needs to understand that the Moon, like the Earth and the Sun, is a solid and spherical object, know that the light of the Moon is actually that of the Sun reflected on the lunar surface and that our natural satellite is 400 000 km away from our planet. A digital planetarium session about the phases of the Moon should take into account these misconceptions in order to properly initiate a conceptual shift from its viewers.

A final aspect should be emphasized with regard to the teaching of the phases of the Moon: spatial skills. Spatial skills are a type of mental skill used by an individual to mentally treat objects in two and three dimensions (Palmer, 2007). These skills are necessary to master astronomical concepts such as the phases of the Moon (Black, 2005; Heyer *et al.*, 2012; Kikas, 2006; Palmer, 2007; Plummer, 2014). It has been shown many times in the past that a session in a traditional planetarium encouraged the development of such skills (Black, 2005; Heyer *et al.*, 2012; Kikas, 2006; Palmer, 2007; Plummer, 2014). Although several spatial skills exist, Black (2005) retains three that are more relevant in astronomy learning: spatial perception, spatial visualization, and mental rotation.

IV. METHODOLOGY

Since the research aims to identify the elements and components of a learning session that are most important to the audience, it will be necessary to develop a session in a digital planetarium that can bring out elements specific to the digital environment. This development should be based on existing theories, but also allow some flexibility and evolution. This evolution will result in different implementation of the session. Following the comments of the spectators at the end of each implementation, the session will have to be modified and improved in order to be able to collect new data with new viewers. This type of methodology is very similar to design experiment (Cobb *et al.*, 2003; Shavelson *et al.*, 2003; Thouin, 2014; Van der Maren, 1996) also known as design-based research (Design-Based Research Collective, 2003). Design experiment is a type of applied research using various theories and aimed at solving problems arising from everyday practice (Van der Maren, 1996). Design experiment does not just produce a "grocery list", but rather interactive systems (Cobb *et al.*, 2003). This allows the production of design theories that can be adapted to new circumstances. Shavelson *et al.* (2003) .describe design experiment as cyclic and based on seven characteristics: iterative, process focused, interventionist, collaborative, multileveled, utility oriented, and theory driven. In short, design research makes it possible to apply and study theories of teaching and learning in their environment while developing educational interventions and improving existing theories (Chastenay, 2013).

The strength of this type of research lies in its types of data and in the bridge it creates with the theory. The use of qualitative and quantitative data allows a triangulation that legitimizes the discoveries. The bridge it creates with the theory makes it possible to check the existing theories by applying them directly in the appropriate context. However, it is necessary to remain vigilant since this type of research places the researcher at the heart of the interventions and modifications of the implementations. Thus, an outside observer might question the legitimacy of pushing the approach in one direction or another (Design-Based Research Collective, 2003). Also, this type of research does not allow the researcher to control all variables (Design-Based Research Collective, 2003) and often, he will only focus on a few parameters. Despite these limitations, we believe that the benefits of using design experiment to create and improve an allocentric session in a digital planetarium far outweigh the disadvantages of this methodological approach.

To date, only the first implementation has been tested. It was presented on February 15, 2017 with about twenty 6^{th} graders (11-12 years old) at the Montreal Planetarium. Several authors agree that the subject of the phases of the Moon is appropriate for this age group (Barnett et Morran, 2002; Kavanagh *et al.*, 2005). Since we are at the first implementation and therefore still at an exploratory stage, we did not pass pre and post-test. The students were all from the same class and it was chosen according to the availability of the teacher, the author and the planetarium. The session was presented and commented live by the author of this paper. An audio recording was made of the session and the group interview that followed. This group interview was semi-directed and aimed at highlighting the elements that pleased or disturbed the participants. It was also a great opportunity to check their understanding of the lunar phases. Since the Montreal Planetarium lent its facilities for free, no fees had to be paid by the class.

V. PRELIMINARY RESULTS AND DISCUSSION

The verbatim analysis of the meeting was done in two different ways: pure inductive and inductive deliberative. As part of this work, pure inductive analysis aims to bring out the elements of the interview without relying on a theoretical framework while deliberative inductive analysis is based on the theoretical framework. In both cases, the Huberman *et al.* (1991) procedure was used for the analysis. This approach proposes to make two rounds of coding in order to bring out the essential of the verbatim. We used the QDA Miner Lite software to code the interview.

Six elements emerged from our analysis, three positive and three to improve. The three positive elements are: the space trip, the immersion and the allocentric point of view of the session. A positive element shared by the majority, if not the whole group, is the pleasure they had to feel in a spaceship and navigate through space. During the session, all the movements were done in a sequence shot. In our opinion, the fact that there is never a break contributes to the sense of presence and immersion. Without being mentioned directly, the allocentric point of view was another positive point. Among the many comments, we retain this one: "*I liked that we could see other moons than ours, including those of Jupiter. And I liked that we could see from another point of view our Moon in space. I knew that the Earth had its phases but I did not know that it was the opposite of those of the Moon*". We can tell the student pleasure he had exploring different points of view, but also that these points of view have helped to teach him key elements to understanding the phases of the Moon.

The elements to be improved for the second implementation are the eclipses, the speed of displacement in rotation and the sounds. During the interview, even before the author asked the first question, one of the students raised her hand and asked, "*But how is a solar eclipse formed?*". This first implementation does not deal with eclipses and obviously, it is an important missing element. Eclipses and lunar phases are intrinsically related concepts and should be presented together. Some students confided that they had been stunned and even nauseous during some rotational movement. It is therefore important to pay attention to the rotational movements so that they are more harmonious. Finally, this implementation included no sound or music. No evidence suggests that the absence of music was a negative factor, but the lack of sound was noted: "*The noise would have helped us because we were sure we were taking off but sometimes it felt like things were moving around. You did not really feel in a spaceship and at other times you really felt like you were on a spaceship*". In short, incorporating engine noises as one travels through space would add to the feeling of presence and immersion. It would also contribute to a better understanding of the scenario and movements in a three-dimensional environment.

Thus, the next implementation of our lunar phases scenario will have to include a section dealing with eclipses, both lunar and solar, and reactor sounds as the "spaceship" moves. The section on eclipses should take full advantage of the allocentric point of view that the digital planetarium allows.

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Interactivity in your sessions: Give the power to your audience!

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BIOGRAPHIES

Working at RSA Cosmos for almost 20 years, Xavier BLANADET developed the first SkyExplorer and contributed to several software developments. Today at the head of the R & D team, he tries to best meet the needs of our customers in terms of features and innovations.

ABSTRACT

Keeping the audience's attention for a long time is an art. The darkness of the dome doesn't help. Soliciting the public is then a great way to keep it alert.

It has been a year since the planetarium of the Cité de l'Espace in Toulouse is using the interactivity in their shows. Several unique concepts have been created specifically for this dome.

In this talk, you will discover several possible uses of voting boxes, from the simple vote to the non-linear session, including the estimation of the satisfaction of your audience.

INTRODUCTION

As a manufacturer, we're moving ideas and concepts to reality. In this process, we need to think about the best way to use a feature.

For everything I will talk about, please remember that I'm not a planetarium user, but a planetarium manufacturer. I don't have specific needs by myself, I'm trying to merge the specific needs of all my customers, and take the maximum benefit of all the solution can do.

I. BUILDING A VOTING BOX

I.1 Technical development

As an introduction I will expose very quickly the different steps of the building process, from the concept to the "first light".

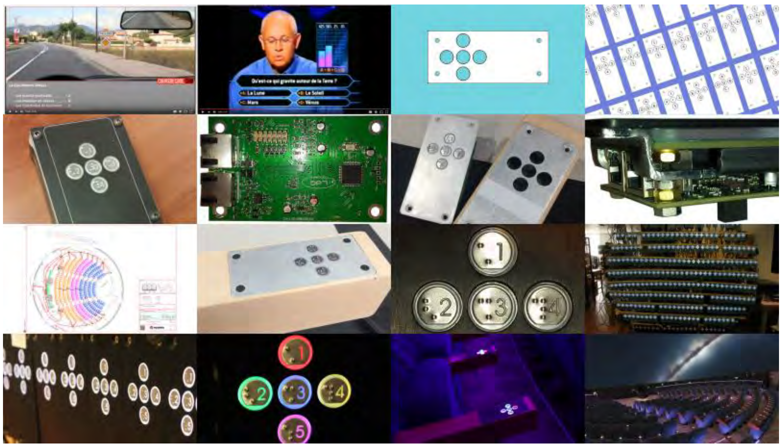

Figure 1 – A Voting Box Story

I.2 Software development

We needed to anticipate the best way to use the voting boxes, to "give the power" to the audience.

We decide to create 5 types of votes. I won't spend too much time on them, since other people will talk about them.

Just let me explain the philosophy of each type.

I.2.1 Take a decision

After this vote, you get a unique answer (even if nobody answered - even if there is equality). This is the first fundamental brick of the interactive session.

The answer is arbitrary; there is no good or bad answer.

I.2.2 Who wants to ... answer the question?

The purpose of this vote is to have up to 5 possible answers, only 1 is correct.

There is a notion of “good” and “bad” answer. This is an important difference with the previous kind of vote.

This is the exact philosophy of a famous TV game.

Physically, the voting box will give you the result: your answer becomes green if good, red if bad (and the good answer is blinking green).

I.2.3 Quizz

This vote is a generalization of “Who wants to … answer the question”. Very complex things can be done.

When you learn to drive, in France at least, there is an exam where you have to answer 40 questions. The “Quizz” is exactly the same thing.

I.2.4 Buzzer

The philosophy of the buzzer vote is: “The faster, the winner”.

The winner’s voting box remains switched on.

I.2.5 Planetarium control

A particular vote is the fact of controlling the planetarium software.

With this vote, you really give the keys of the dome to your audience!

Example: Ride in the Saturn’rings, Fly across Valles Marineris, or simply control a pointer.

I.2.6 And after the vote?

We offer the software to run a show at some very precise moments.

For instance: when a Quizz ends, you can run a show or another depending on the selected answers. If the audience didn’t correctly answer, you can automatically run a more detailed explanation, this enables you to have better results.

Concerning the “Take-a-decision vote”, the “post-vote script” is the second fundamental brick of the interactive session: depending on the result of the vote, the system will do such thing or such another.

II. INTERACTIVE SESSIONS

II.1 Concept

A standard real time session is 20-40 minutes long. During this part, the animator will talk about many different subjects, according to his own pedagogic organization, choices, culture and so on.

That means that he/she spent some time (hours/days) in brainstorming to find the best and smartest way to explain such and such complex concept (gravity, light, time, ...).

The result is a travel from a point A to a point B, with more or better knowledge in B that there was in A.

In this situation, the spectator is passive, just like any student at school, and the way he will learn will only depend on his/her ability to learn and the experience of the teacher.

The main idea is to let the spectators choose a part of the session by themselves, so that they're implied in the learning process.

The spectator becomes active.

The current mean to achieve this is to choose 1 sequence among N.

Advantages and disadvantages

- Curiosity more satisfied
- Better memorization
- Better profitability for the spectator
- Successfully duty for the planetarium
- Good word of mouth / Loyalty
- Educational interest
- Financial interest
- Less educational coherence
- Poor profitability of the exposed contents relative to the real used ones
- More work to prepare the session

II.2 Prepare the session: a methodology

The first fundamental brick is to “take a decision”. The second fundamental brick is to “automatically run a show”. Using those two bricks will help you in building the interactive session from scratch.

Before exposing this methodology, we need to estimate the effort an interactive session will require to be prepared.

II.3 Theoretical preliminaries

So spectators will choose 1 proposal among N different ones.

Imagine that N is constant and equal to 2.

If spectators are solicited once, that means that the mediator needs to prepare the first half of his session normally. But he needs to prepare 2 different "second-half".

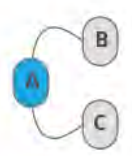

Figure 2 – Interactive session with 1 solicitation and 2 choices

Relative to a standard session, he will work 150% (1+2 instead of 2). That means that only 67% of his work is really effective.

Even worst, if spectators are solicited twice, the mediator will prepare 1+2+4=7 different segments for only 3 finally used (43%).

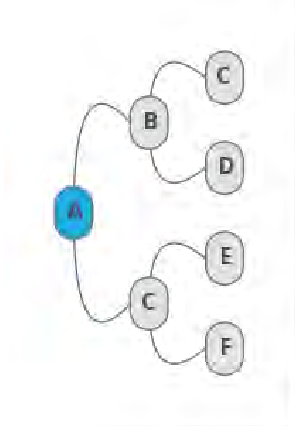

Figure 3 – Interactive session with 2 solicitations and 2 choices

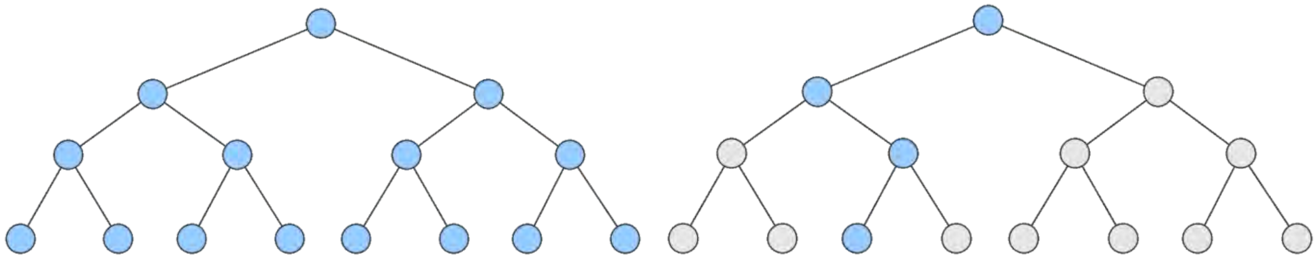

Figure 4 – The shows of a simple interactive session: Proposed vs Really shown

With 3 solicitations this rates drops down to 27% (15 proposed on the left for 4 finally shown on the right).

And this is with N=2, so imagine with N=5

If we consider the ratio of the prepared sequence over the really-used sequences, the interactive session has a very low one.

If spectators are solicited P times with N choices, then this ratio μ is:

$\mu(N, P) = (P + 1) / (N^0 + N^1 + ... + N^P)$

$\mu(N, P) = (P + 1) * (1 - N) / (1 - N^P+1)$

N \ P	1	2	3	4	5
2	67%	43%	27%	16%	10%
3	50%	23%	10%	4%	2%
4	40%	14%	5%	1%	<1%
5	33%	10%	3%	<1%	~0%

Table 1 – Effectiveness of the prepared sequences

The way to read this table is: in all the sequences that I proposed to the spectator, how much did he really saw?

Obviously, the more you want to customize your session, the more work you'll have to prepare the sections. You can't build your session at once. You have to find the best compromise and you need to iterate.

Thus the idea is to put one foot in front of the other and to re-use the resources several times, in different sections.

II.3.1 The first interactive session

Today you got a set of Voting Boxes, but you don't have any sequence or content prepared in order to take benefit of them.

Let's start with a single vote between two different “astronomical” news, to finish your session: “Latest Curiosity discoveries”, and “The gravitational waves”. Each one of those news is a 2-minutes scripted show, live commented.

The week after, you can add a third sequence, talking about a third astronomical news, while keeping the two previous ones of course.

Then, weeks after weeks, you can add some new sequences.

But you only have 5 possible choices – because you only have 5 available buttons. When you reach the 6th vote, you need to kick one of the previous ones, which goes back to your sequence pool and thus remains unused.

This is where it becomes interesting. Because weeks after weeks, you add more sequences and give up others. The more your sequences rotate, the more your pool grows.

Then you can add a second choice. And then here comes the interactive session.

II.3.2 The sequence pool

Now that you have a nice and ever growing sequence pool, you have to organize it, because you'll quickly get confused.

The way you organize your pool is up to you.

This is my pool example (on the next page). Please remember that I'm not a scientific mediator by myself - this is purely theoretical. I chose a mind map to organize my pool.

When you have a more complex pool, you will have to choose the more interesting scripts, depending the latest news. This is the most interesting part of the interactive session: filtering and sorting the pool’s sequences in order to build a show “à la carte”, and walk through them just like in a gamebook.

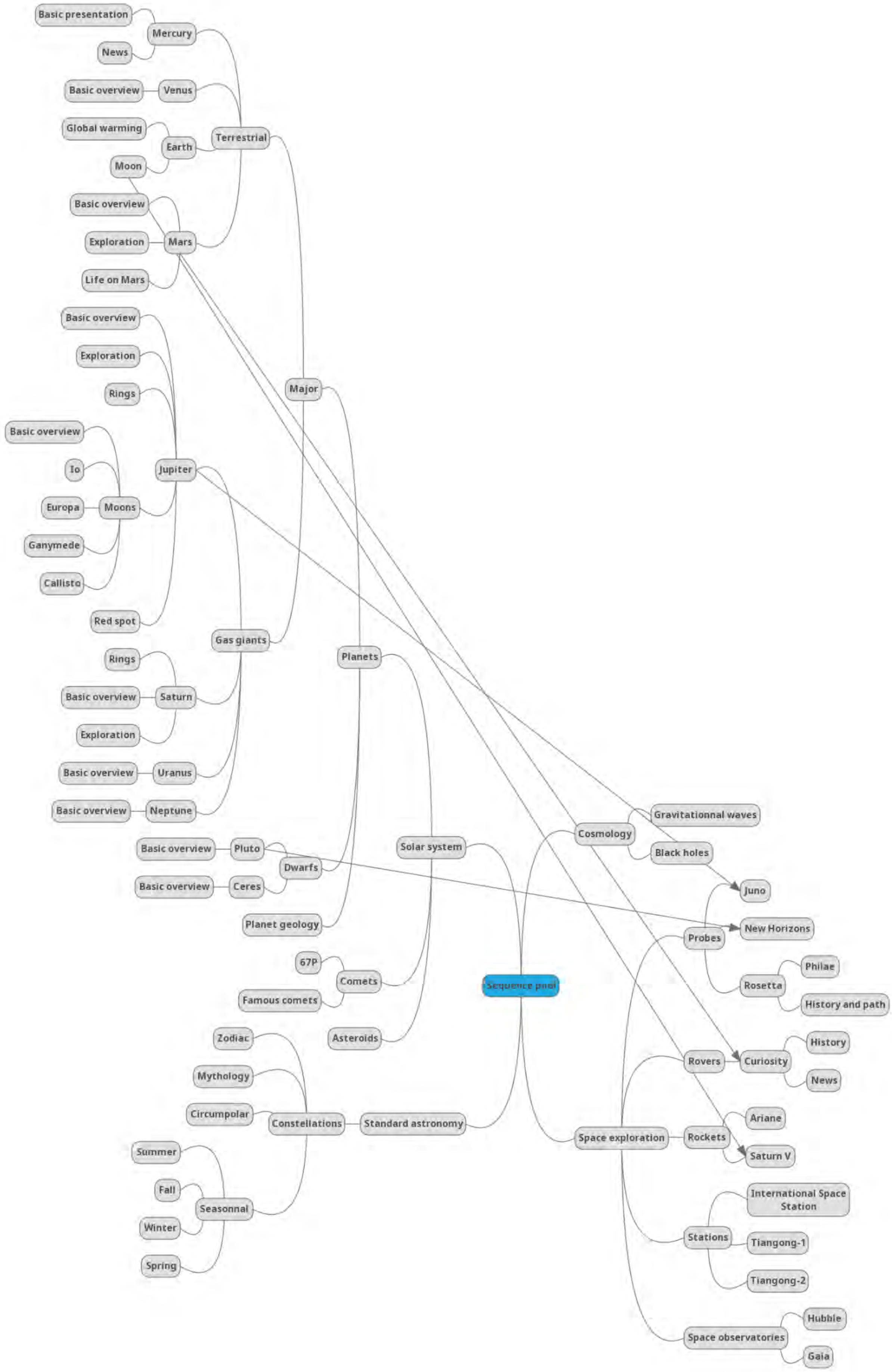

Figure 5 – Sequence pool example

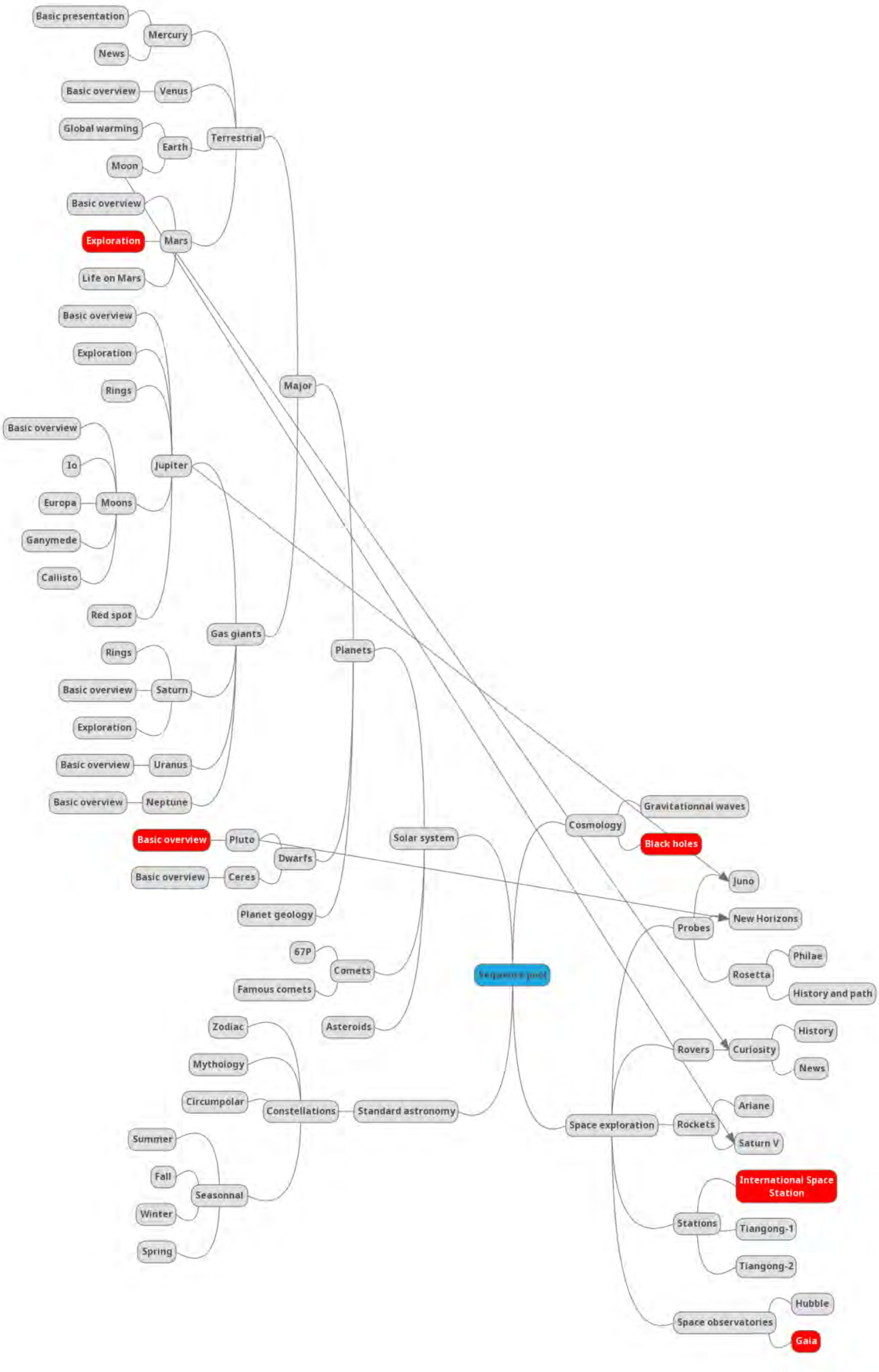

Figure 6 – Pool extraction

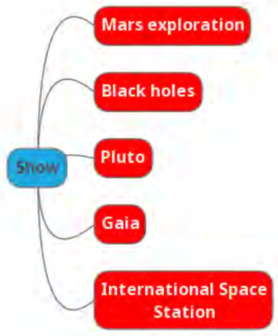

Figure 7 – Pool's extraction resulting vote

II.3.3 The pool's life

After several years, you'll have a nice sequence pool.

You made a script for Rosetta's launch in 2005. Then, in 2016, you had to talk about Rosetta's "rendez-vous" in 2016. The comet is still the same, the probe didn't change, many things are still the same. That means that you have many reusable sequences.

Another example: "Osiris-Rex launch" in 2016, "Osiris-Rex orbit insertion" in August 2018 and "Osiris-Rex sample acquisition" in July 2020. For each IPS, Osiris-Rex offers us new things! But Bennu is still the same.

Then you can just pick up some older sequences from your pool to round off your interactive session.

In the previous example, if you want to talk about the latest news of Curiosity, you can grab 3 other sequences from your existing sequence pool and add a new level to your session.

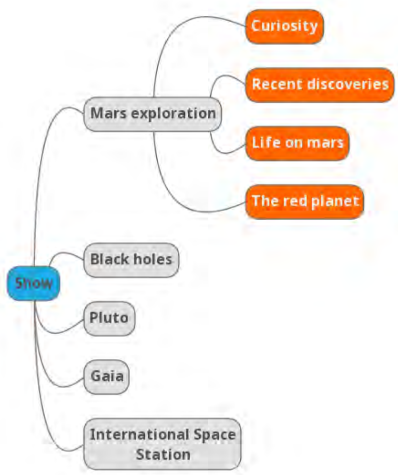

Figure 8 – Completing a session with existing sequences.

As a conclusion: the bigger pool you have (and there is no need for it to be so huge), the easier it is to recycle the interactive session bricks to cover the latest news, with less efforts.

III.HELPERS

This part will list some feature that can be used to tune up the way you give the “power to your audience”.

III.1 Group management

The group management enables you to separate your audience in groups.

You can use this in different ways:
- Select only the occupied seats (very useful for adjusting statistics)
- Make a competition (only winners can participate to the next vote)
- “Reds” against “Blues”

III.2 Statistics

The statistics can be used in 2 main uses:
- The result of each vote (keeping results in CSV files for later analysis)
- Specifically ask something to your audience (“Did you like this show?”)

The analysis of the vote results will help you to have a much better knowledge of your audience.

And asking them explicitly their age, their school levels, or so, will help you to corroborate this with the vote results, in order to build more effective shows.

And if you’re a Planetarium Director, you may also be interested by knowing how much the audience liked such show.

III.3 Adjusting / Influencing

When solicited, people will often (always) choose the same thing. If 40% of people are interested in visiting the moon and 60% in visiting mars, 100% of the votes will be "visit mars". Then "visit the moon" will *never* be chosen and people will never appreciate this part of your work.

The only way to influence the vote is to tease the sequence (with a video preview for instance? Or with a quick description). This will be useful to equilibrate the choice (load balancing). This can also be _before_ the vote, in order to influence it.

IV.EVOLUTIONS AND IDEAS

IV.1 Add programming language for advanced behaviors

We can imagine extending the SDK and accessing directly to the results of the vote using a programming language (such as Python) and taking decisions from the script.

We can also imagine building votes dynamically (the 5 last APODs for instance), or even implementing a serious-game engine using the voting boxes, such as a scientific escape game.

IV.2 More interactivity with audience

We can imagine going further the physical voting box and have a QR code on the Voting Box to be flashed, so that you can “connect” your voting box with a specific app to get your result and stats for instance.

V. CONCLUSION

The voting box system is a very interactive way to give the control to your audience. But this is very time-consuming and requires a hard work in order to build the initial sequence pool.

But after some months, you will be able to take benefit of your rich pool by reusing sequences.

Combined with analysis features, you can offer the way to your audience to customize the show according to their wills, while you’ll learn to better understand them, such as their knowledge, their trends and so on.

Thank you for your attention.

Blender for planetaria: low-cost fulldome content creation for everyone

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BIOGRAPHIES

After completing a PhD in Gravitational Wave Data Analysis, Edward moved to the Royal Observatory Greenwich to be part of the Science Learning & Public Engagement team. Amongst other duties, he is part of a smaller team creating content for the Peter Harrison Planetarium, including fulldome shows for external distribution.

ABSTRACT

This workshop session is designed as an introduction the open source 3D creation software Blender, with a focus on using this software to create and share free fulldome content amongst the planetarium community. The basic functionality of the software will be explored, but the main intention is to get interested parties to connect in person at IPS2018. By encouraging skill-sharing, and perhaps the establishment of joint projects, we hope to foster the ambitions of existing Blender users (and turn other people into Blender users!) to help create content for everyone.

INTRODUCTION

Planetarians are often hungry for new content to enhance their shows, or ambitions to create their own, but is this possible without significant resource? Is low-cost fulldome content creation feasible for everyone? We want to explore one possibility.

The paper format here is perhaps not best suited to a participatory workshop. In an attempt to encourage participation and keep things as simple as possible, the content below will serve mainly to suggest intended talking points at the workshop, and some practical information about acquiring the software ahead of time.

I. BLENDER AT A GLANCE

Blender describes itself as a free, open source, 3D creation suite. Its goal is to be a complete pipeline for modelling, animating, compositing and rendering content: in their own words “Open Source 3D creation. Free to use for any purpose, forever.” In theory, anything from short clips to full shows can be created, without the need for expensive hardware or additional software.

I.1 Blender in the planetarium

Though the software has a huge number of features, *cameras* within the 3D space are simple to set up and define characteristics for. This makes creating and controlling a fisheye lens to output renders in *domemaster* format is trivial. This alone represents an extremely beneficial starting point for interested planetarians.

However, while there is an active creator community- with a vast amount of tutorials and free samples online- the specialised nature of producing fulldome content means most people are self-taught, and are adapting techniques and material designed for flat-screen work. Developing fulldome-specific skills will be an important part of empowering the community to create relevant content.

I.2 Acquiring the software.

The main Blender Foundation website is the best place for up-to-date versions of the Blender software. In the workshop we will aim to use the stable distribution **Blender 2.79b** available here: https://www.blender.org/download/

Windows, macOS and Linux versions are available on the same page.

We encourage anyone who is interested in participating in the workshop to download and install the Blender software ahead of time, and bring a laptop to follow along with any demonstrations or share project files. However, anyone wishing to simply come and have a look or ask questions is more than welcome. For all of its potential, Blender can be a little unfriendly for new users, and we want the workshop to be a useful introduction and a way for others to decide if they want to get involved in 3D creation in the first place.

I.3 Other software versions and plugins.

To keep things straightforward, we will not try to encompass earlier versions of the software, nor any of the experimental development builds/branches. We intend to discuss the upcoming **Blender 2.8** overhaul, but will not rely on it since it is not in full stable release yet.

We will not rely on -though participants may wish to talk about- paid plugins or modifications, or anything that is not available through Blender's own module library. Similarly, we do not intend to demonstrate the Python API or scripting in general, though we would be very interested in users with experience here to contribute to the meeting.

II. THE WORKSHOP ITSELF

This workshop is for anyone who is interested in creating content for their planetarium using Blender. Beginners will learn about the basic functions of the software and be supplied with some project files to create some quick pieces of content.

II.1 A general invitation

No expertise will be assumed, and there is no set outcome intended for the workshop itself. Existing users are encouraged to come along and share their techniques with everyone, as well as their experiences using the software.

We simply want to get people talking: Blender could be a great way for planetaria with similar goals to collaborate, and the workshop will be a space to see if your ambitions match anyone else's. The IPS community has a huge range of talents and expertise, and this would be an exciting way to pool the resources we have to create something that benefits everyone.

II.2 Project files

The intention is for project files to be lightweight enough to share easily during the workshop itself, using a shareable Google Drive link, or physically sharing an external hard drive pre-loaded with the relevant files. The files will also be available throughout the conference itself to any interested party who makes themselves known to Edward, or anyone else who has already acquired the files.

II.3 Workshop format

The rough idea, as stated previously, is to present the software and demonstrate a few techniques useful for fulldome production. However, without a set outcome in mind the workshop will be open to anyone to exhibit their own work or query other users. It is likely that we will touch on hardware requirements too, as well as the integration of Blender-rendered content in various planetarium software systems (or other software packages), but we expect the participants will set the agenda in an open manner.

Attendees who know they wish to speak are encouraged to come and speak with Edward beforehand: we will attempt to make sure some time is allotted within the loose structure of the workshop. Nevertheless, the plan is not to tightly control the proceedings, but to provide a space to discuss low-cost fulldome content creation for everyone.

Stars and Discoveries

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BIOGRAPHIES

Isabel Borges
Presently is the Education Coordinator at the Planetarium C. Gulbenkian - Ciência Viva Science Centre in Lisbon. Has a background in Chemistry Engineering, Degree in Physics and Chemistry Teaching, Master in Pedagogical Supervision and several trainings in NASA, ESA, CERN, Eurofusion, RAL-lasers, Science Museums and Planetariums. Works on (and learns about) Science Education, Space Sciences, Astronomy and Science Communication.

Cláudia Faria
Presently, is a Principal Researcher at the Instituto de Educação da Universidade de Lisboa. She has been developing research in science teaching, namely in promoting a closer relationship between formal and non-formal science learning contexts (science centres and museums). Has a PhD in Biology and a PhD in Science Education.

ABSTRACT

Stars and Discoveries describes a planetarium program visit with a mobile App *Roadmap of the Discoveries*. This free downloadable App is a cultural and scientific tour exploration offering different itineraries through a set of museums, monuments and places in the city of Lisbon, all related with the Portuguese Discoveries. When visiting the Planetarium participants explore the itinerary *Trought the Sea*: night sky watch, ships, sky maps, telescopes and astronomical navigation instruments as used by the Portuguese Navigators from the 15th century are some of the ingredients of this experience. With no disciplinary subjects, this itinerary involves and engages visitors through scientific ideas, experiences and emotions, characteristics of non-formal education in a planetarium science centre.

INTRODUCTION

We describe a planetarium visit program to promote science literacy guided by the mobile App *Roadmap of the Discoveries*. This is part of a wider project with the same name created in the Science Education Department of the Institute of Education of the University of Lisbon (http://www.ie.ulisboa.pt/didatica-das-ciencias/app-roteiro-dos-descobrimentos).
It also includes other visit programs to a Museum, an Aquarium and walk paths through some historical monuments and old districts of the city.
Roadmap of the Discoveries uses the richness of content and new ideas of the Age of the Discoveries in the 15th century when Portugal began the process of globalization from its capital, Lisbon. At that time, Portugal was a country with a small population of slightly more than 1 million people and yet, Portuguese were among the first ones to connect the World through the sea. One may say they were the founders of the first global worldwide "internet". Perhaps, the human crusade closest to the actual Space Exploration was the Portuguese Expansion, in the sense that the human kind steps into an abyss of unknown in search for new lands. At that time, instead of space ships and *gps* there were caravels and astronomical navigation.
These cross ideas are in the core of Portugal History and Culture, involving subjects from areas such as science, technology, mathematics, biology, geography, business and languages. Moreover, these contents are learning targets of the Portuguese school curriculum.
The App *Roadmap of the Discoveries* with its several Itineraries is scientifically validated and a tested learning resource for STEM (Science, Technology, Engineering and Mathematics). Mainly targeting school groups, this visit program is also recommended for families or other groups, in a non-formal science learning context such as the Planetarium.
Trought the Sea is the itinerary to visit the Planetarium Calouste Gulbenkian - Ciência Viva Science Centre and resulted from the cooperation between the Institute of Education of the University of Lisbon and the Education Coordinator of the Planetarium.
This Planetarium, a 23 meters diameter dome in Lisbon, was built due to Commandant Conceição Silva, officer of the Portuguese Navy for sky watching and to teach astronomical navigation techniques to young cadets of the Military Navy School.

With ships, maps and astronomical navigation instruments as used by Portuguese navigators and, through an inquiry-based science learning (IBSE) methodology, the Education Department of the Planetarium takes participants in an adventurous story they will remember long after their visit.
Learning outside the classroom, associated to the IBSE methodology, favors the contact of students with problems and challenges of their daily life, contributing to a better understanding of science and the scientific process.
The museum environment provides opportunities for youth to connect with science in personally meaningful ways, develop their own science identities and consider pursuing science careers, through exhibits, activities, and extended programs (Adams & Gupta, 2013; McCreedy & Dierking, 2013). Curriculum expanded learning environments comes alive in planetariums, forest and nature, parks, libraries, market place, Science centers and museums, aquariums, homes for the elderly, etc.
Learning outside the classroom also promotes motivation, creativity, critical thinking and the ability to work as a team. Participants begin to ask questions and to seek answers as they engage with content (Renninger, 2007).

I. THE PROJECT *ROADMAP OF THE DISCOVERIES*

The Portuguese Age of Discoveries began with the Infant D. Henrique and the conquest of the African coast, having elapsed during the reign of D. João II, with the discovery of the maritime route to India and the reign of king D. Manuel I, during which the overseas empire was already consolidated. This historical process made a decisive contribution to the knowledge of the world and the relationship between its many civilizations.
Roadmap of the Discoveries can be explored in a family or in a school context for children 4-6th grades. It is based on a free computer application for Android system mobile technology devices (Fig. 1).

Figure 1 – Roadmap of the Discoveries: a project to learn Science

It proposes the exploration of some monuments, institutions and places of the City of Lisbon associated to the period of the Portuguese Discoveries, between the 15th and 16th centuries. It offers several possible itineraries, taking place in different Monuments and Museums of the city, focusing on the History, the encounter of different Cultures and Languages, the Astronomical Navigation and the Biodiversity of the Oceans.
For the production of the educational contents, partnerships were established between the Institute of Education (University of Lisbon) and three non-formal Education Departments (Planetarium Calouste Gulbenkian - Ciência Viva Science Centre, Museum of the Orient and Aquarium Vasco da Gama).
The production of the App *Roadmap of the Discoveries* was coordinated by the Institute of Education of the University of Lisbon in partnership with the Department of Informatics of the Faculty of Sciences of the University of Lisbon, which was responsible for creating the software application for mobile Android system.
This was a project funded by EEA Grants under the program PT02 - Integrated Management of Marine and Coastal Waters, promoted by the General Directorate for Marine Policy.

The App can be downloaded from Google Play Store here:

English: https://play.google.com/store/apps/details?id=pt.roteirodosdescobrimentos

Portuguese: https://play.google.com/store/apps/details?id=pt.roteirodosdescobrimentos&hl=pt-PT

The visit itineraries of the *Roadmap of the Discoveries* are the following:
1. Itinerary *Trought the Sea* – Planetarium Calouste Gulbenkian – Ciência Viva Science Centre
This dimension addresses issues associated with astronomical navigation. Here participants are led to discover the differences between a caravel and a ship, the astronomical navigation instruments used in maritime trips and their function, the references found by navigators to sea orientation, the importance of astronomy and constellations and the cardinal points. They explore life on board, including issues such as food (storage and conservation) and hygiene (scurvy, for example, a disease attacking sailors due to lack of vitamin C).

2. Itinerary *Monsters and other marine creatures* - Aquarium Vasco da Gama
This itinerary address marine biodiversity of the different oceans sailed during the sea voyage from Portugal to India. It includes 3 stations:
The first one corresponds to the fish gallery of the Portuguese coast, promoting students´ understanding about the morphological characteristics of fishes associated with their way of life and habitat.
The second station corresponds to the area of the museum of the Aquarium and it is intended that students learn about marine mammals, live species and their main threats. Students must associate some of these marine mammals with known marine mythological monsters.
The third station runs in coral and tropical fish aquariums area, introducing students to some species of coral, the importance of coral reefs and its current threats. The question, why in Portugal there are no coral reefs is also raised.

3. Itinerary *The City at the time of the Discoveries*
Three routes related to this dimension are carried out in various places in the city of Lisbon.
The first in Belém, along with the main monuments associated to the Portuguese Discoveries, including the Jerónimos Monastery, the Tower of Bethlehem and the Monument to the Discoveries. A photographic Pedy paper game acquaints participants with the importance of some Portuguese figures who stood out in this period, and promotes the exploration of the *Manueline* architectural features and the Portuguese colonization symbology .
The second station corresponds to Mouraria and Alfama, two historical districts of Lisbon, where students are expected to discover architectural elements of the *Manueline* period. Sixteens points can be visited and participants have some observation tasks associated to some of them.
The third station includes downtown: Commerce Square, Ribeira das Naus and Rossio. In this course, students are invited to discover how the city of Lisbon was like in the fifteenth century, comparing it with present-day. Issues such as transports, clothes, the type of events held and the organization of the city are focused. For example, the analysis of the painting "Panels of São Vicente de Fora" shows the different social groups existing at the time.

4. Itinerary *People and Cultures – The entire World in Lisbon*
This dimension addresses aspects related to cultural diversity and the encounter of cultures through the voyages made during the time of the Discoveries.
Two of these routes are in Martim Moniz and Mouraria, two historical districts. One is related to language diversity in that area where it is possible to observe records written in different languages. Participants are asked to associate them with a type of alphabet: Latin, Cyrillic, Greek or Hebrew. Along the route, students may associate countries to the respective languages, from the 51 nationalities present in this area of the city, and explore a little more about the Portuguese language (which is also spoken in other countries). Students will also analyze Chinese characters and will try to decipher some of the proposed challenges. The second route takes place in the same area and takes an approach to the Hindi language and Indian culture, having gastronomy as a background.
The third route takes place in the Museum of the Orient including a visit to the exhibition "Portuguese Presence in Asia". Here it addresses some important Portuguese figures of the time of the Discoveries (Luís Vaz de Camões, Fernão Mendes Pinto, Vasco da Gama) and some aspects of the different culture characteristic of some countries where the Portuguese lived and had commercial connections (India, Japan, China, Macau).

II. THE VISIT TO THE PLANETARIUM

The visit program to the Planetarium has two learning activities: *Sailing with the stars* (under the dome) and *Astronautical Navigation Instruments* (outside the dome). This visit includes guidance on the mobile App (Fig. 2) as well as a planetarium show (optional). Both learning activities were developed by the Education Department of the Planetarium.

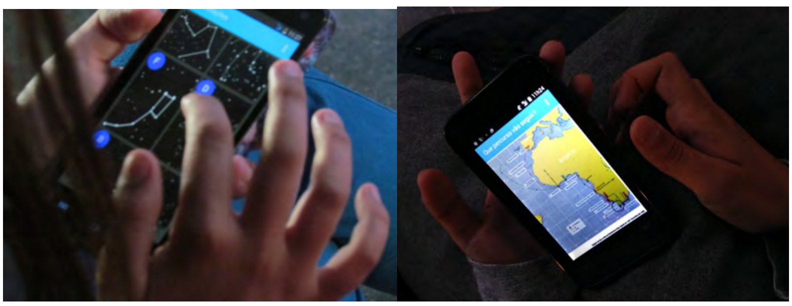

Figure 2 – Exploring the itinerary Roadmap of the Discoveries App

Under the planetarium dome, *Sailing with the Stars,* requires a live show to perform this adventure from the 15th century under a starry night sky (including constellations, Polaris, meridians, Equator). Live shows are more recommended to school visits

and contribute to better fulfil public visitors´ expectations. However, it is important to have a good presenter to succeed in promoting interaction and answering questions from the audience.
We combined the live show with two other elements: the interaction of participants (who have to move around the central area of the planetarium to "sail" and have to locate some constellations with the support of transparencies) and some audiovisual effects (video of a ship sailing rough sea, waves and wind, clouds interfering with sky gazing, sound waves, thunder storm, sea sounds, etc.).

II.1 Under the dome - *Sailing with the Stars*

The activity starts with an invitation from the presenter to participants: "*let´s go back in time*" and a story begins…
It all began in the 15th century when the European Maritime Expansion started. Most people lived in poverty. Between the periods of famine, disease and war, of that period of the History of Europe, people and countries sought for richness and power.
Within this context, the Portuguese Age of the Discoveries was a whole national movement leading a wide range of expeditions to the ocean in order to increase territory and influence.
Most peasants knew from their childhood that a life of hard labor and possibly years of poverty was the most likely to expect. On the other hand, some of them acknowledge new alternatives, like joining the military or joining a sea expedition to the "unknown".
In the early 1400s, sailing needed to have the coast in the range of sight for guidance. The navigation far from the coast would only be possible with the reference of the stars by night or, the presence of the sun during the day. So, an urge to develop observation techniques, instruments and maps and the so-called astronomical navigation soon led to technological breakthroughs. Not only did the instruments become more sophisticated, ships and vessels got larger and faster, but also food storage and preservation technics, medicine and hygiene developed greatly.
Participants take a role play: they are just poor people from the 15th century …"You don´t know how to write or read, you don´t have a mobile, internet, medicines, vaccines, medical care, electricity, clean water piped and no decent roof, …, you are very poor, you may even have to steel to put some food in your children`s mouth …
Let´s go on board … and come back home rich!
A brief discussion is promoted with participants about arrangements for the expedition: food, water, equipment, etc.
During the sea travel we sailed across deep seas, far … far away from the coast. Like navigators from the Age of Discovery, we managed to guide our ships under the stars!
Participants have to look up for constellations, for example, Cygnus or Orion (Fig. 3). They understand the meaning of a constellation and of an asterism. They have to find North so they learn how to locate the Big Deeper, the Small Deeper and the Polar Star.
They identify and locate some other constellations in the Northern Hemisphere.

Figure 3 – Searching for constellation patterns in the night sky under the dome of the planetarium

The Western European culture, inherited from the Greek and Romans, imagined gods and mythological characters in the night skies, whilst other cultures in the world watched the same stars but imagined different images and constellations.
"*Days, weeks, even months pass by ... The sea is rough and the sound of waves is loud ... storm is coming ... With luck, after the storm fades we hope to have a clear sky to find our way guided by the stars or by the sun ... And let us pray for good winds... The Polaris is going down and down on the horizon …the Line of the Equator is right above our heads … new stars and new skies come on sight… Where are we going to? Reaching the Southern Hemisphere, we meet the unknown. A whole new sky is above us*."
Participants sail across the ocean guided by the stars just like in the Age of Discovery navigators did. Towards the South they discover new stars, feel the need for new references and create new constellations. Then, turning South Cape of Africa from the Atlantic Ocean to the Indic Ocean, they overcame the Cape of Storms later named Cape of Good Hope!
Participants understand the role of Astronomy, constellations or cardinal points to navigate across the seas.
The presenter has to ensure the viewpoint is correct to observers' location as they travel along Earths´ surface. He shows the night sky, points out some constellations and talks about how and why our viewpoint changes.
One last subject focused in this activity is to observe the light pollution´s effect on the night sky and perceive the factors that produce it and other related issues. All steps of this activity should be simple to set up with any adequate planetarium software.

II.2 Outside the dome - *Astronautical Navigation Instruments*

The position of the Sun in the sky guided sailors along the sea travels. Bu how did they managed to find the right direction and don´t lost themselves in the large oceans? Which instruments did they use? Let's put hands-on to build a quadrant, to learn how to use an astrolabe, to measure the height of the Sun, know the latitude and also observe our star through the telescope!

This *hands-on* and *minds-on* activity uses some navigation instruments as used in the 15th century (Fig. 4). Participants build simple quadrants and learn how to use it by measuring the height of the Sun. They also learn to use an astrolabe and compare measurements, noticing complementarity between the two instruments in a way they minimize reading errors. Then they learn to read Sun Declination Tables to succeed to calculate the local latitude.

Figure 4 – Students measure the height of the Sun with a quadrant they build himself and with an astrolabe

During this activity participants watch the Sun through a telescope equipped with filters and interact each other and with the mediators. It is very important that mediators give communication opportunities to participants.
For this activity we use calibrated copies of original astrolabes and quadrants from the collection of the Maritime Museum of Lisbon. To build the quadrants we use the *Kit Latitude & Longitude*, an education resource from *Ciência Viva*® available online here:
http://www.cienciaviva.pt/equinocio/

III. EVALUATION AND SOME FINAL IDEAS

The App *Roadmap of the Discoveries* takes users in a continuity of activities across multiple locations, which is an affordance for learning that mobile devices can provide. It may be explored autonomously by the user.
Based on on-site observations and historical information, a diversity of tasks was developed in the App: drawing, interpreting writing messages, connecting ideas, observing, classifying, selecting information, assembling puzzles, previewing and reasoning. For student groups there are some classroom challenges like planning and researching, to do before or along the visits.
An evaluation study of this App was done by the team researchers of the Institute of Education of the University of Lisbon. A participant observation of 8 teachers and 131 students (8 and 11 years old) has been carried on to understand students´ and teachers' opinions. A questionnaire about the use of the mobile phone, aspects that they liked, difficulties felt and aspects that facilitated learning, as well as lessons learned was applied. Moreover, a semi-structured interview to teachers and to groups of 5-6 students brought up information about the application popularity, the impact on learning and about the use of technologies during teaching and learning processes.
The results about what students learned provided evidence that this App is a relevant didactic resource to teachers and other professionals, who use digital games in a learning context. The App showed to be a different way for students to have contact with the information and with different historical contents associated with the various monuments, also implying cooperation between peers to overcome the different challenges proposed. It took students to discover their city. Some students told that they showed their parents the App and that they showed surprised by what they have learned. Teachers even stated it has been gratifying to have had this opportunity with their students.
Students also emphasized a greater interest in learning, as they felt they were active participants throughout the visit, as well as, getting new perspectives and overcoming some challenges showed to be more interesting than just looking or hearing someone speaking during a visit.
According to the 2014 U.S. Mobile App Report, 60% of digital media time in the U.S., for instance, takes place on mobile devices. This represents an opportunity for the field of informal STEM education to reach children where they are already spending time.
Moreover, the OECD (2015) stated that technology can support new pedagogies that focus on learners as active participants with tools for inquiry-based pedagogies and collaborative workspaces. For example, technology can enhance experiential learning, foster project-based and inquiry-based pedagogies, facilitate hands-on activities and cooperative learning, deliver

formative real-time assessment and support learning and teaching communities, with new tools such as remote and virtual labs, highly interactive non-linear courseware based on state-of-the-art instructional design, sophisticated software for experimentation and simulation, social media and serious game.
It seems that we are only in the beginning of one possible new era where mobile technologies will be tools of transformative museums, planetariums or science centers.
A good presenter can create a great show using even simple visuals and interacting with visitors: He may update or change content, allowing participants to come to the "same" visit program more than once. A presenter can also adjust content to answer questions and promote genuine interest, besides contributing to build a planetarium reputation.
We humbly hope these ideas, and the project described in this article, may be adapted, or be useful or, at least, may inspire other planetariums.

ACKNOWLEDGMENTS

We acknowledge the Institute of Education and the Informatics Department of the University of Lisbon and EEA Grants.

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Very live show

Mateusz Borkowicz, *Copernicus Science Centre*
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BIOGRAPHIES

Mateusz Borkowicz, astronomer from birth. For many years, the popularizer of astronomy. Live show presenter in planetarium and radio presenter.

ABSTRACT

My speech will be the essence of the experience of running live shows. The problems and issues that I take are the importance of personal approach to shows, the role of the presenter and the tricks to use. In the foreground there will also be recipients and interaction, then appropriate music selection. People in today's world are accustomed to special effects and that is what they expect when visiting a modern planetarium. It turns out that not quite! Since the beginning of our civilization it is also important to establish a common language. This will be a guide to working with the public.

INTRODUCTION

Viewers in the planetarium want to first of all listen to stories about stars, constellations and see them. Fulfill their expectations and give them much more! Live shows conducted in a duo (presenter + producer) are the best thing that can meet the audience, thanks to this they have the opportunity to meet an authentic man who reacts to them.

I. ART OF PRESENTATION

I.1 Warm-up

The strength of the warm-up and major impact in the live show and contact with the audience. A good warm-up helps to reduce stress and focus on important things first.

By using the warm-up every day, you do not have to worry about losing your vocal cords. In addition, you will be able to speak fluently for a long time.

I.2 Our/ their goal

After a solid warm-up you have to think about what we want to achieve and focus on the expectations of the audience. It is a smart way to get this very important knowledge: just talk to guests!

I.3 Scenario.

The role of the script in live shows. Should it be detailed and extensive?

The times when everything must be in accordance with the scheme have gone into oblivion. The show time should not be rigid but it must have certain margins. Today, it is not necessary to tell everything, it is worth leaving understatements to interest the audience. Remember to let people enjoy the beauty of the sky.

Do not overload their heads! Here, minimalism is very important, but only used wisely.

I.4 The art of presentation - the basics.

In this part, we will meet with the most important rules on the stage during public speaking. The right body posture and how to we keep the microphone, it say a lot about us. Voice play at the right moments and the use of onomatopoeia will certainly revive our show. Smooth transitions between scenes or thoughts do not always have to be smooth. It's elegant, but it's not allowed to overdo it.

Keeping in touch with the audience may seem quite difficult, even for 10 people, but there are several ways, such as triangulation.
To make the show even more vivid, you have to be an authentic man and do not throw ridiculous jokes.

A pause is also very important, but only properly used. It will help you relax a little more and give the audience a moment alone with the stars.

I.5 A bit of theater. A bit of stage fright.

Pay attention to the actors' playing, take a good look and try to find things you could use. Certainly they often have to deal with stage fright and they have their own ways to do it: they control their breathing.

I.6 Like in radio studio

As a radio presenter, I noticed many similarities at work as a live show presenter. The dome of the planetarium, after switching off the lights, becomes a very similar space, you stay with the listeners who only hear you at this moment. It's worth using this to play with voice and using a good soundtrack - it's worth having support in this.

II. PERSONALIZATION

II.1 Your specialization

It's your strength, people using it will see an authentic man. Do you have any experience or stories related to observing the sky? Tell me about it and feel the shivers on your skin!

II.2 Searching for inspiration

In each team we find people with different talents and passions - this should be your inspiration. Expand your horizons and watch your colleagues try to learn new things. In my team there are: a theater actor, philosopher, physicist, sound engineer and programmer - from each of them I learned many new things. Co-workers can give you very honest feedback and vice versa. Its good way to perfect yourself.

The show is like a living organism, respond to the audience, use their involvement and interaction. During a breakdown and unexpected situations, do not ignore this, because people are happy to get to know the planetarium backstage.

II.3 Inattentive audience - tricks.

Inattention or disturbance during show is a common problem, even when you talk very interesting. It happens not only to children and young people, also adults.

Paying attention in a traditional way will not necessarily give the desired effect. You can spoil the interaction with the audience that scares you. Be gentle, do not get distracted, come closer to the person who interferes and act by your very presence. It's simple and it works! Develop your own method, check it, experiment!

II.4 Special effects? Multimedia!

Take advantage of technology, today you have the option of setting your own workspace. You can add your own music, if you can not, someone will help you! Personalize your music so that the show will be a very comfortable experience for you, and it will translate into your viewers.

Did you took a photograph of Jupiter with your phone through binoculars? It is worth showing this to people during the show, thanks to which you will gain authenticity and the viewers will find out how simple it is.

II.5 Self-criticism + voice emission training = success

The above tips will help you feel more comfortable during the shows, and the audience will appreciate your work.

To succeed, it is worth giving in to self-criticism. Record video or audio of your speech and check what and how you can improve, find 3 things that bother you the most and then change them. Repeat this periodically, the effect is warranted.

Use voice trainer and video guides or books, lets voice training – voice it's your job tool now.

My Favorite Audience Warm-up, "Find the Planets"

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BIOGRAPHY

Dr. Ann Bragg is the Director of the Anderson Hancock Planetarium at Marietta College in Marietta, Ohio, where she is also an associate professor of physics. She presents outreach programs to all ages and teaches physics and astronomy classes across the undergraduate curriculum. She enjoys bicycle touring in her spare time.

ABSTRACT

I begin most live star talks by pointing out the planets currently visible in the sky that we are viewing. To make this process more interactive, I ask the audience members to locate the planets and have them "guide" my laser pointer with verbal directions. Both correct and incorrect answers can lead to fruitful discussion, and shouting out directions early in the program helps loosens up the audience. Introducing this element of uncertainty into the beginning of my live shows also helps keep my presentation from getting stale over time. I plan to demonstrate how this works for me in practice and hope to hear what works for other planetarians.

INTRODUCTION

Outreach programs at the Anderson Hancock Planetarium generally consist of three parts: a live star talk using our opto-mechanical GOTO Chronos star projector, a fulldome video, and a live question & answer time. I begin most of the star talks with the planet-finding activity described in this presentation. I will describe/demonstrate how this activity proceeds and then I will discuss its benefits.

I. DESCRIPTION/DEMONSTRATION OF ACTIVITY

After the lights have dimmed and the night sky is visible on the dome, I tell the audience how many planets are visible in that night's sky. Next, I ask them to look around and see if they can find any of the planets. After giving them several seconds to look, I ask if anyone thinks they have found a planet. I usually receive positive responses and then ask where they are looking. Sometimes an audience member will suggest a cardinal direction, but other times I will get responses such as "Over there!" When I receive the latter type of response, I will ask specifically about whether they are looking north, south, east, or west. Once someone provides an answer, I aim the laser pointer near the horizon in that direction and then ask the audience to guide my pointer to the possible planet. The audience guidance can get quite vocal at this point, especially if audience members disagree about the location of the planet (or if I am deliberately clumsy in my direction-following!) Once my pointer lands on an object that at least some of the audience agrees is a planet, I ask them why they think it is a planet and which planet they think it is. Then I let them know what they have actually located.

When bright planets such as Jupiter or Venus are visible, the audience generally finds them quite easily, though they often do not correctly identify which planet they have found. At this point, I may briefly describe why these planets are so bright from Earth, as well as the fact that Venus is in the west when visible in the evening sky. The audience also usually does well locating Mars, though sometimes they will instead locate a star such as Betelgeuse or Antares, which provides me with an opportunity to explain that some stars are also red.

Saturn and Mercury are much more difficult for the audience. When one or both of these planets are visible, the audience will often select multiple bright stars before finding the planets, which often requires the help of a few clues. Then we can discuss why these planets are more challenging to spot and how ancient peoples could tell planets and stars apart. When three or more planets are visible across the sky, I may introduce the idea of the ecliptic. When an object is identified by the audience as Uranus or Neptune, we discuss how these planets are only visible with telescopes and were only discovered relatedly recently as a result.

II. BENEFITS OF ACTIVITY

Asking the audience to locate the night's planets definitely takes more time than simply pointing them out to a passive group. I have found that beginning a show this way has a number of benefits that are well worth the time investment.

II.1 Engage Audience in Actively Looking at the Sky

When asked to locate planets on their own, audience members look more critically at the sky and begin to make judgements about which objects might be planets. This exercise gets them viewing the sky more actively throughout the rest of the star talk and better prepares them for viewing the real sky on their own. After being forced to commit to which objects they think are planets and to identify their directions in the sky, I believe that visitors are more likely to remember the actual planet locations after the show.

II.2 Engage Audience as Active Participants in the Show

Beginning planetarium shows with an audience-participation-heavy exercise sets a very different tone than beginning with the presenter broadcasting lots of information to a passive audience. It sends a signal to the audience that their own observations of the sky are important, that it is okay to respond audibly to the presenter, and that their input is valued. After beginning a show this way, I generally find my audiences to be more responsive throughout the program and more inclined to ask questions at the end. While it might seem that there is a risk of opening the floodgates to disruptive behavior/questions throughout the program, I have never had a problem with an audience member derailing a program through excessive interruptions as a result of inviting their participation.

II.3 Introduce Spontaneity into the Show

When presenting numerous planetarium programs, it is easy for the content of the star talk to start to feel stale. I am surely not alone in sometimes feeling like my voice and my laser pointer are indicating constellation locations without any actual participation by my brain. Audience participation helps me avoid this state. When they are directing me to planet locations, it is different every time. I cannot simply repeat what I said to the last group because things happen in a different order and sometimes a totally unexpected object is identified as a potential planet (such as the LED light on the classroom projector in the back of our dome!) Sometimes interesting misidentifications by the audience can lead the show in directions that I never would have planned on, but that are worthwhile and that meet the audience where they are in terms of understanding and interest.

The experimenta and its Science Dome

A new combination of show stage, multimedia dome, and planetarium

Kenan Bromann, Dr. Kai Noeske, *experimenta gGmbH Heilbronn-Germany*

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BIOGRAPHIES

Kenan Bromann, Head of Technology / Science Dome
Kai Noeske, Manager, Science Dome and Observatory

ABSTRACT

Upon re-opening in early 2019, experimenta will be Germany's largest science center with a total area of 25,000 m², equipped for all formats of STEAM science communication; including a state of the art "Science Dome".

INTRODUCTION

The experimenta, a hands-on science center located in Heilbronn within a central area of German technology industry, has been operating since 2009 and has welcomed 180,000 visitors per year.
A current massive renewal project includes the construction of an architectural landmark building. Upon re-opening in early 2019, experimenta will be Germany's largest science center with a total area of 25,000 m², equipped for all formats of STEAM science communication: 9 modern laboratories, 4 permanent hands-on exhibition worlds, special exhibition areas, classrooms, open research and science maker spaces, talent-finding labs as well as an astronomical observatory with powerful instruments and additional telescope stations to host larger groups.

I. HISTORY

The idea to set up a Science Center in the former "Hagenbucher" oilseed storehouse, the only remaining remnant of the industrial complex on the island in the Neckar river, was born in 2005 in the Department of Culture headed by Harry Mergel. Dr. rer. nat. habil. Wolfgang Hansch developed the first content-based concept.
On March 2007, the non-profit association "experimenta – Science Center der Region Heilbronn-Franken gGmbH" was founded as the operating company.

The Science Center finally opened its doors on November 14, 2009.
Until experimenta's last day in its previous form, on July 30 2017, the Science Center inspired first and foremost children, teens and families to explore scientific and technical subjects. Experimenta welcomed more than 1.3 million visitors so far.
The new experimenta with its spectacular new building and converted existing structure is the largest Science Center in Germany. Its almost 25,000 m² exhibition area is a unique world of knowledge and experience. The sole source of funding is Dieter Schwarz Stiftung gGmbH.

Of special interest to the IPS is the Science Dome, an innovative facility that mates a tilted 21,5 meter multimedia dome with a full-size theater stage, located on the side opposite the dome's primary viewing direction.

Figure 1 – Artist impression of experimenta and its Science Dome

II. THE NEW EXPERIMENTA OVERVIEW

When experimenta reopens in the first quarter of 2019 it will be the largest Science Center in Germany. A spectacular new building in glass and steel complements the previous domicile in the historic Hagenbucher storehouse which is also undergoing extensive renovations with an extraordinary variety of offerings.

II.1 The Discovery worlds

With more than 250 interactive exhibits, four exhibition areas will spark interest to investigate our scientific curiosity and teach us how to ask questions. The Discovery Worlds will provide very concrete insight into current science and research.
Unique digital products are also created: whether photograph, video or text, everything will be stored in a digital backpack and saved in a personal account. Visitors can access their backpacks easily from home via internet.

II.2 The Research worlds

Eight high-quality labs, an experiment kitchen, the Northern Württemberg Student Research Center and a Maker Space provide a wide range of experiments.

Figure 2 – Student Research Center

II.3 The Experience Worlds

The Experience Worlds uniquely round off the diverse offerings of the new experimenta. Plays and demonstrations in the observatory and astronomy workshops, 3D shows, science demonstrations or concerts and lectures held under the Science Dome are offerings that give visitors a truly special experience.

III. THE SCIENCE DOME

From the outside, an elegant dome nestled into the experimenta campus, from the inside, an exceptional high-tech experience space: the Science Dome offers visitors of all ages a way to immerse themselves in unknown worlds – without visual limits.

III.1 Multimedia highlights

This is made possible by high quality multimedia and technical stage equipment in the Science Dome, creating a multi-sensory atmosphere that is unrivalled in our multimedia world: with wind and fog machines, a water curtain, state of the art laser technology and a close to 700m² screen in the dome.
On stage live events become highlights of the experimenta program that leave long-lasting impressions – whether theater production, concert, reading, lecture, live broadcast or interactive experiment demonstrations in which the audience experiences live just what high tension means.

III.2 Revolving auditorium

The revolving auditorium in the Science Dome is a unique feature. After a 180 degree turn of the auditorium, visitors find themselves under a state-of-the-art planetarium or before a theater stage.
Science and art come together in different form of shows whether on stage or under the dome, or both of them. Visitors can lean back in comfort in the flexible seats (150) of the Science Dome and be fascinated by the daily phenomena and world of science.

III.3 Technique in short

- Rotatable Auditorium
- Theater Stage
- Curved Cinema Screen and side screens
- Laser- and Videoprojection on Waterscreen
- 3D Audio System
- 665 m² Projection Dome 21,5m Diameter
- 3D 360°-Fulldome-Videoprojection 8K 60fps

- ZEISS- Universarium
- Planetarium (Software, Servers)
- Unique Dome and Stage combination

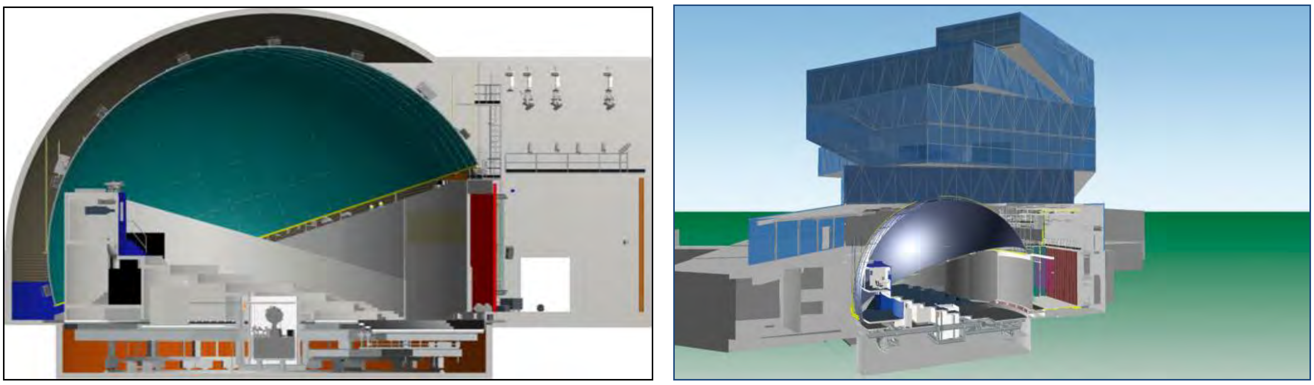

Figure 3 – Sections of the Science Dome

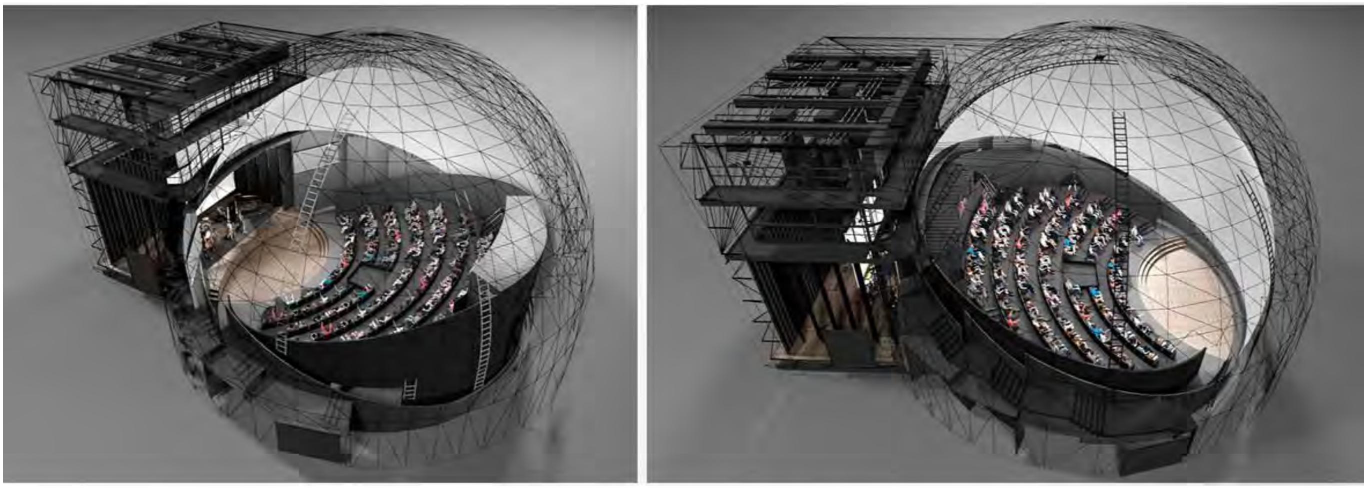

Figure 4 – Stage modus versus Dome modus

III.4 Content

The Science Dome team has its own production team under supervision of Dipl. Designer Ralph Heinsohn. Beside experimeta's own productions the team provides additional footage for VR environments, models and other screens.
Licensed shows are also in play and special attention is given to stage productions for different age groups which combine the use of the revolving theater.
Stage Science shows are created on different topics. Special attention will be given to High Voltage Shows since 3 Tesla coils are installed on stage for permanent use.
The use of a combined stage and dome modus gives unlimited possibilities for dramatization of different productions.
The rotation itself will be part of these experiences.

Figure 5 – Art and Science on stage

III.5 Challenges

To change between dome- and stage viewing modes, the entire 150-seat audience platform can be rotated 180 degrees. The Science Dome is equipped with 8K dome projection, 3D audio, lighting and recording systems, digital planetarium image generators, an opto-mechanical star projector, a laser system, projection water screen, additional cinema projection screens, complete stage technology, can be linked to the rooftop observatory and is prepared for high voltage and chemical experiments.

The Science Dome will be operated continuously on a dense schedule, with content from all STEAM and related fields and formats ranging from full-dome movies, planetarium and live experimental shows to concerts, theater, talks, music and laser shows. Shows are developed for different age groups, covering all ages and targeted to also attract youths and young adults.

Finding the optimal way of using the combination of dome, stage and ample multimedia technology poses challenges, and offers opportunities to gain insights useful for the world-wide planetarium landscape as it develops towards digital, multi-purpose multimedia domes.

IV. THE OBSERVATORY

The Observatory and the Science Dome are two high-tech cupolas that allow visitors through time and space. Powerful telescopes under a 6,5 meter All-Sky Dome with a combined refractor and reflector will be opened daily for visits or observations. An Observation deck is available for occasional sun observations.
Especial access for handicapped persons is provided.
Astro workshops on different levels will be part of the tasks of the observatory team. Cooperation with experienced astronomers from the Robert Mayer Observatory in Heilbronn is in full swing.

Figure 6 – experimenta Observatory

Portable Dome Horrors!

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BIOGRAPHIES

Ben Brown founded Explorer Dome with Shaaron Leverment in 1998 and they have created one of the UK's leading science outreach organisations presenting lively, hands-on science shows to over 50,000 people every year. Josh Yates joined the team in 2006 and they now operate 4 mobile domes, a series of chemistry shows & workshops and represent E&S's Digistar Lite in the UK & Ireland on behalf of Skypoint srl. With 20 years on the road, thousands of school visits, training and management of 50 professional planetarium presenters and over a million children seeing their shows they look forward to sharing their experiences and hearing from the international community.

ABSTRACT

In a break from the usual format, this is a session is all about sharing! Let's share the deepest darkest and most horrible experience inside your mobile dome, why they happened and how you overcame them. Anyone had problems with schools overbooking students into shows? Any issues with health and safety when the teacher leaves the dome half-way through the show? Sound familiar? What about payment, travel, longs days, exhaustion, cancellations and terrible student behaviour? Have you had someone die inside your dome...? One of our facilitators has! (although the individual was resusitated.)

This session has 2 aims: let's share some of these stories that only happen to us - the mobile dome planetarium presenters! It is likely we share similar experiences and can benefit from hearing inventive solutions. We also want to share the success: We also want to share the success: How do you get that re-booking? How do you expand? How have you managed to be here in Toulose, when so many portable domes have not found enough work to continue?

This is a session dedicated to enjoying our international similarities and differences. Let's find out a little about how much we have in common with nations around the world and, we hope, how much we can learn from each other.

Full details of this session will be submitted following the session with a record of who attended, what secrets were shared (where appropriate!) and what solutions were discussed. Watch this space…

THE SESSION

Taking place in a wonderful mobile dome (with integrated inflatable seating!) set up within Cite de l'Espace's Astralium, the session was attended by about 20 delegates from Japan, Czech Republic, UK, USA, Italy, France, Spain, Korea and Poland for a truly international flavour.

Delegates included those operating mobile domes as vendors, private businesses, academic institutions and as part of a science centre's outreach provision, including one institution aiming to provide a mobile dome temporarily while their main dome is closed for refurbishment.

Various topics were discussed and some solutions offered, but the primary benefit of the session seemed to be to share experiences with each other and learn how much we all have in common. Portable Dome Horrors included:

- Audience falling asleep – common in fixed domes, but rare in mobile domes
- Presenter falling asleep – many delegates had experienced working exceptionally long hours, feeling tired while driving and having to take un-scheduled breaks with resulting audience criticism (95 shows in 4 days in one case!)
- Power cut – most often caused by operator error/carelessness, but the need for emergency lighting emphasized
- Medical – awareness of who is responsible for First Aid; one operator experienced a child suffering epileptic fit resulting in heart stopping, although swift medical intervention resuscitated the individual; DLP projector flickering suspected as a possible trigger by some operators
- Young children crying a frequent issue
- Mobile phones and associated light/noise also causing frequent problems

- Finally, the winning horror was reportedly experienced by the Travelling Telescope in Kenya (although they were not present to support the anecdote) where armed militia interrupted a show and the operators had to keep the show going at gunpoint without knowing until afterwards whether the soldiers were hostile or friendly.

Stonehenge

Susan Reynolds Button
IPS Portable Planetarium Committee
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BIOGRAPHY

Susan Button, a retired teacher and mobile dome director, is a past president of IPS, has chaired the Portable Planetarium Committee since 1988, and has been a member of the International Relations Committee since 2017.

ABSTRACT

This presentation will be an abbreviated version of the Lawrence Hall of Science PASS program, "Stonehenge." Visitors predict where sunrises and sunsets will occur along the eastern and western horizons during different seasons. The observations are conducted in the context of judging if the English stone circle of Stonehenge could have been used by its builders as an observatory and calendar.

Cover photo from PASS program "Stonehenge"; collage elements include Solar Eclipse, courtesy of Peter Michaud and Stonehenge, courtesy of Gerald S. Hawkins.

WORKSHOP

Stonehenge is a prehistoric stone circle located in southern England. The mystery of why and how it was built is still not completely understood. Some basic understandings have developed due to the curiosity of archeologists and astronomers.

Gerald Hawkins, an astronomer, entered the positions of the standing stones and other features at Stonehenge into an early IBM 7090 computer and in 1963 he claimed that his findings showed that Stonehenge was built to serve as an astronomical observatory. Since computers were such a new technology, his findings received a great deal of attention. Although some of his claims are still in question his ideas sparked the development of a new field of study, "Archeoastronomy." Astronomers became more interested in archeology and archeologist became more interested in astronomy. And so began a more intense study of how the sky played a role in the lives of various cultures and how the structures they build may help to decode that role.

This program uses the mystery of Stonehenge to introduce, or reinforce, celestial motions and the changing position of the sun's rising and setting positions through the year as participants try to determine if Stonehenge is indeed an astronomical observatory and calendar.

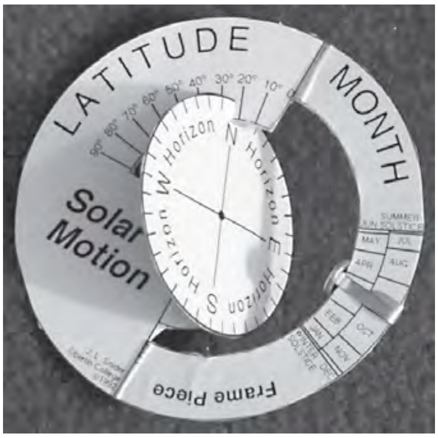
The target audiences for this program include the public and students 9 years of age and older. It is designed to highlight how new ideas arise and are tested using scientific methods. It also demonstrates how one person's ideas can have a profound influence beyond their initial intent.

The Stonehenge show first introduces how Gerald Hawkins was inspired by the fact, discovered a few hundred years ago, that on the first day of summer, the Sun as seen from the central area of Stonehenge rises almost exactly over one particular stone, now known as the "heel stone." This information led him to investigate if the other stones marked any other astronomical events. During the presentation participants are guided to follow the steps he took to validate his predictions by using a map, similar to that used by Mr. Hawkins, to reconstruct Stonehenge and using the planetarium as a "computer" to check the possible alignments.

The planetarium is set at minus 3550 years (the last major phase of Stonehenge was completed about 1550 BC), if precession available, and at latitude 51 degrees north. Students experience marking sunrise, noting noon, predicting sunset and looking at other celestial objects as possible alignments. By projecting the positions of the stone archways (Trilithons) of Stonehenge on the dome, students can test sun, moon, bright star and planet rising and setting positions to see if any celestial event can be seen through the stone openings in the archways on any particular dates. They learn that the stones could have been be used to mark the solstices.

Several supplemental activities are provided that can be used to enhance this show:

1. Azimuth and Horrizons
2. Where’s East and West?
3. Creating a Horizon Sun Calendar
4. Many Moonrises
5. Solar Motion Demonstrator
6. Sunrises at Stonehenge



We will focus on just one of those activities during this workshop. We’ll learn to use a simple device called a “Solar Motion Demonstrator” that will be supplied fully assembled. This device accurately models the apparent motion of the sun (rising and setting points as well as the altitude of the sun at noon) at any time of the year and any latitude in the northern hemisphere of Earth.

Since this device is designed for the Northern Hemisphere; we will discuss how it might be redesigned for the Southern Hemisphere.

Solar Motion Demonstrator from PASS Stonehenge program. Designed by Joseph L. Snider.

ACKNOWLEDGMENTS

The Solar Motion Demonstrator was designed by Professor Joseph L. Snider of Oberlin College. The design and directions for use are copyrighted by Professor Snider. You may reproduce them as needed for your own classroom or planetarium but not for commercial purposes.

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Planetarium Activities for Successful Shows (PASS) **Stonehenge:** http://www.planetarium-activities.org/shows/sh and for other PASS programs go to: https://www.lawrencehallofscience.org/programs_for_schools/curriculum

I is for International

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BIOGRAPHIES

Susan Reynolds Button is a past president of IPS and has chaired the Portable Planetarium Committee since 1988. She is a retired portable planetarium directorfor the Onondaga Cortland Madison BOCES in Syracuse, New York, USA.

Loris Ramponi, Italy, is the founder and the secretary of the national Association of Planetaria (since 1986) and the coordinator of Serafino Zani Astronomical Observatory and Planetarium and other organizations.

Sharon Shanks has been editor of *Planetarian* since 2006. She retired as planetarium lecturer from the Ward Beecher Planetarium at Youngstown State University, USA, in 2015.

ABSTRACT

The “I” in IPS stands, of course, for International. There are several ongoing IPS initiatives to promote international collaboration, but we feel that even more are needed. We will briefly explore these efforts, and also propose additional efforts to reach out even more to IPS members of non-English-speaking countries. The topics of our paper will include the International Day of Planetariums, An Astronomical Experience in Italy for an American Planetarium Operator and A Week in United States professional development experiences; and the Voices from the Dome project. We also will report and expand upon a proposal to promote *Planetarian*, the IPS journal, through translations and recordings, particularly for countries where English is a barrier for some planetarians to become new members of IPS.

INTRODUCTION

We planetarians deal with cosmogony — those stories and myths that explain the what and why of how things came to be. We all have stories that explain how the stars and constellations got into the sky, how the world was created, and where the first people came from. You can think of them as the first tentative answers to the really hard questions that people have always asked.

There is one origin myth that especially pertains to us, today, in this room, in this city, in this country, on this continent, and on this planet: The Tower of Babel. Similar to Greek/Roman tales of hubris and how the constellation of Cassiopeia got into the sky, the story explains why people speak different languages.

The Tower of Babel by Pieter Brueghel the Elder (1526/1530-1569), located in the Kunsthistorisches Museum in Vienna, Austria. Photographic reproduction of public domain work of art, Wikimedia Commons.

Once upon a time, people thought they would come together in one great city and build a tower that reached to the heavens. God was not pleased and smote them – well, he didn’t kill them, but he made them speak different languages so they could not communicate with each other and thus no longer join to make great things.

It did not work.

Planetarians speak different languages, but we still make great things happen. We inspire awe, share wonder, foster inspiration: these are things we do every day through the shared language of the stars.

We are here today because the International Planetarium Society holds conferences like this once every two years. We subject ourselves to early mornings, long days, hours under the dome, and sleepless nights so we can learn from one another.

The I in IPS. It is the first letter, and the most important. It is this society’s commitment to work together as a worldwide society, one that ignores political boundaries and sees only one sky. And sees many languages.

The fact that we speak different languages has been a problem since people started talking. The need to understand each other is important on every level: from the most basic needs (like finding the bathroom) to the most important (like the continuing existence of our planet).

The official language of IPS is English. I (Sharon) sometimes feel guilty about this fact, because it is an automatic barrier. But, because of that old Tower of Babel, we need to communicate in *some* language, and we have managed, thanks in large part to the rest of the world teaching English in their schools. Some of you listening are proficient in English (you would make your teachers proud), and others, not so much. But you are here, nonetheless. **Despite differences in language, you are here**.

So, attending conferences like this one and meeting each other face to face is a huge step to forming collaborations that transcend language.

For an example of this, please check the June issue of *Planetarian*. (Vol. 47, No. 2, p. 40). In it is a story titled "From Chicxulub to Tunguska: The story of two impacts and friendships that spanned the globe."

> *The story about a fulldome show titled From Chicxulub to Tunguska begins at a dinner during the IPS 2016 meeting in Warsaw, Poland, when the president of Planetarios Digitales, Enrique Fonte and Jessica, his wife from Mexico, sat down and met at the same table with Pavel Nikiforo, director of the Irkutsk Planetarium, and the planetarium's public relations manager Eugenia Skaredneva.*
>
> *The chance of a trip planned months before by Enrique and Jessica through the huge Siberian region and the warm willingness as Eugenia and Pavel's guide in the city of the Irkutsk and Baikal Lake resulted in a strong friendship that would cross borders.*

What a wonderful illustration of openness and cooperation, resulting in an educational program that benefits both countries. **Despite the differences in language, they made it work**.

Another step toward working together is shown in efforts by IPS to promote international collaboration by other means, including the International Day of Planetariums, professional development exchanges in Italy and the United States, and the Voices from the Dome project. And still another project is being developed: to promote *Planetarian* through translations and recordings, particularly for countries where English is a barrier preventing some planetarians from joining IPS.

I. INTERNATIONAL DAY OF PLANETARIUMS

The International Day of Planetariums, the idea of Associazione Amici dei Planetari, has been around since 1991. Other planetariums joined in the celebration starting in 1995. Planetariums in some countries have been participants for many years; others took part for this first time this year. In fact, IPS itself did not take an active role in promoting IDP until recently, but now is committed to making the day succeed and grow.

The goal of IDP is to involve the international planetarium community in a collaboration that promotes knowledge of planetariums to the public. There are various ways to do this, all covered well on the IPS website.

The Astronomical Center Rijeka Planetarium in Croatia has been hosting a Day of Planetariums since 2010, part of its very active public outreach. They shared their schedule for the day and a news release announcing it on the website.

This year, IDP focused on portable planetariums, a special shout-out to the work of mobile planetarium educators and how they positively impact their regions. You can read about the winners — from China, Great Britain, Costa Rica, and Japan — in the June *Planetarian* and on the website. **Despite the differences in language, they made IDP work**.

II. A WEEK IN …

There are two professional development and cultural exchange programs available to planetarians. The first is An Experience in Italy for an American Planetarium Operator, sometimes shortened to "A Week in Italy," even though the week is 10 days long.

The Serafino Zani Astronomical Observatory began hosting the event in 1995. You have been reading reports in *Planetarian* each year from the winners. In 2017 it was IPS President Shawn Laatsch; this year, it was Kevin Milani of Hibbing Community College in Minnesota. His report will appear in the September issue.

Each year the people in Perugia, Assisi, Brescia, and Gorizia are warm and welcoming hosts.

The second exchange program started just last year. It is A Week in the United States, modeled after the Week in Italy program. It is sponsored by the IPS International Relations Committee.

The first year was a resounding success. David Gruber from Italy spent a week at the Casper Planetarium in Wyoming, and Matthias Rode and Tilo Hohenschlaeger were hosted by the Emil Buehler Planetarium in Florida.

This year's winner has already been name: he is Ullar Kivila from the AHHAA Science Center in Estonia. He will visit Minnesota this fall, and his report also will appear in *Planetarian*.

In addition, The Week in the United States also has acquired a generous donor, who has pledged to support some of the travel expenses every year. He is Ted Pedas from Farrell, Pennsylvania; some of you might recognize his name from astronomy-themed cruises on the former Royal Olympic cruise line based in Piraeus, Greece. As an international traveler himself, he said he wanted to encourage the ability of others to travel as well.

Both of these programs are designed as a way for planetarians to widen their horizons. People in this room right now know that it is by travel to unfamiliar places that teaches us about how wonderful and different the world is and how people, no matter their language, are so much alike. It is by face to face interaction with people that we develop empathy for others. This is how strong collaborations are formed.

IPS hopes that other countries will join in this effort by sponsoring their own "Week in My Country" experience. We will be happy to work with you to set it up; all you need to do is to communicate with us.

And, despite the differences in language, we make the weeks in Italy and the United States work.

III.VOICES FROM THE DOME

So far we have talked about face to face communication: how planetarians share with the public on the International Day of Planetariums, and how planetarians travel to different countries to learn and to educate. I would like to talk about verbal and audible communication: the recording of our voices to be shared around the world.

Voices from the Dome is an international project with the motto of "many voices, one sky." Like all of the projects we have described, it is open to all planetarium operators. We are collecting short audio clips to use directly in planetarium shows. Or, they can be used in professional development, as examples of how experienced planetarium leaders present stories to the public.

The objective is continue to increase the collection of audio clips prepared by planetarium colleagues worldwide and available on the resources pages (free media, audio) of the International Planetarium Society web site.

We have audio in Deutsche, English, Francais, and Italiano, and are always looking for more languages. We need collaborators from different countries! You will see me with my recorder during the conference collecting more material. You also are welcome to make your own recording — you can even use your phone — and send it to me for inclusion. The format is mp3.

Some clips are simply "welcome to the planetarium" in your native language. Imagine how happy that will make visitors — let's say from China — when they hear "welcome" in their own language when they visit your dome.

You never know how the clips will be used. For International Space Week this past October, a radio show host named English Bob, working from a studio in Portugal, discovered the Voices from the Dome audio archives on the IPS website. He used the voices of astronomers from Germany, Tasmania, and the United States for a weekly program he calls Cultural Popcorn, producing a mix of astronomy and space music. It would be difficult to be any more international.

He said "To add to the space-related songs, sci-fi and movie themes, I was searching online for some interesting space-related audio clips, and was delighted to discover the International Planetarium Society 'Voices from the Dome' project. I was looking for short, engaging, introductory pieces that did not require any prior knowledge of astronomy. What I liked about these clips is they were accessible, and covered different aspects of space exploration. But for me, the most important thing was that each clip captured both the experts' enthusiasm for astronomy and their sense of wonder at the universe." (*Planetarian*, Vol 47, No. 1, March 2018, p. 11)

IV. *PLANETARIAN* IN MANY LANGUAGES

Our newest audio project is being developed right now. Planit — the Italian Association of Planetaria — is sponsoring this original project with the support of IPS and *Planetarian*, of course. Simply, it is the preparation of audio comments, in native languages, of each issue of *Planetarian*.

There is so much good information in *Planetarian*, but English continues to be a barrier in some countries, like Italy. To help non-English readers, Planit proposes that collaborators from many countries prepare audio comments for each issue. The short audio, only 3 to 5 minutes, collaborators could comment freely on an article of interest to their country. It could list the titles of the articles, with short comments. It is not necessary to produce a detailed translation.

Here is part of a script of a radio program that I (Loris) recorded in which I talk about the *Planetarian* translation project, provided here in English and Italian.

Authors' note: The following section will be presented live and will be added to this paper at the conclusion of the conference.

The audio clips about the issue will be available on *Planetarian's* section on the IPS website, and also can be shared on your affiliate's website.

V. CONCLUSION

There are many ways that IPS members can become involved with IPS: by serving on committees, by taking part in conferences like this one, and, simply, by becoming a member.

But IPS also wants to be involved with you, to serve you and the planetarium field in the best way possible. To do that, we need innovative projects that help overcoming the language barrier that the Tower of Babel produced.

The I in IPS also can stand for Inclusive, and also for Input. We need both to make the I in International really stand out. **We, together, despite the differences in language, can make IPS work**.

And now it is time to ask, where do we go from here?

Science Communication Through Motion Design for Fulldome

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ABSTRACT

In 2015, the Porto Planetarium and ESAD – College of Art and Design developed a partnership in order to explore new ways to present scientific concepts for display through digital and immersive media.
The result of this partnership was the production of several short fulldome videos, aimed at different age groups, covering topics in astronomy such as exoplanets, galaxies, spectroscopy, asteroseismology, dark matter, comets or constellations.

INTRODUCTION

The Porto Planetarium (hereafter Planetarium) completes 20 years in 2018. It was created in a very specific environment, built from the outset so that the creation of scientific knowledge in astronomy and astrophysics (A&A) lives in close connection to the promotion of scientific culture and the dissemination of knowledge and attitudes, especially to young people. It is still operated within this context, being run by Centre for Astrophysics of the University of Porto (CAUP) on behalf of the University of Porto. CAUP is also the host institution of Instituto de Astrofísica e Ciências do Espaço (IA), the largest Portuguese research centre in A&A, which scientifically supervises the Planetarium activities.

The Planetarium is a member of the Network of Ciência Viva Centres. This is a network of twenty science centres in Portugal, led by Ciência Viva, the National Agency for the promotion of initiatives for the public awareness of science and technology in Portugal. The network mission is to promote an active citizenship based on scientific knowledge.

Until the spring of 2014, when major overhaul works started at the Planetarium, including moving into a digital projection system, all planetarium sessions where own productions. The move to a digital system represented new opportunities, but also tremendous challenges regarding the in house production of fulldome digital contents.

ESAD – College of Art and Design argues that schools, in addition to awarding academic degrees, must be formative institutions in the full sense of the term, establishing themselves as communicating platforms between the civil society, industry and the market. The daily life of ESAD is intense, diverse and productive. Classrooms, workshops and studios are open to cross-cutting or specific activities and to interdisciplinary or specialized tasks. It is intended that students can experiment, test and produce in an assisted manner by teachers and technicians.

ESAD's post-graduate course in Motion Design aims to prepare the students for the labour market, exposing them to a fast and continuous pace of task fulfilment, staying as close as possible to the reality of the work. The main goal of the course is to provide the students with comprehensive and consolidated theoretical-practical knowledge in the fields of communication, narrative and development of concept.

This is the environment that allowed for a partnership between the Planetarium and ESAD, experimenting with the production of short fulldome movies.

I. OBJECTIVES AND METHODOLOGY

In this experiment, developed in academic context, small groups of students from ESAD'S post-graduation in Motion Design were challenged to produce short fulldome movies conveying an astronomy subject or concept.

This work was articulated between the Planetarium, which seeks new ways to explore science communication in a fulldome environment, and ESAD where teachers and students defined the following specific objectives and methods, that materialized the transmission of scientific knowledge:
– an understanding of science as the foundation that supports the translation of concepts to visual representation, and its articulation with visual representations from different areas of knowledge;
– a reflection on the role of visualization in the knowledge transfer process, empowered by the immersive experience;
– a discussion between Studio and Client, on the proposals for alternative representations;
– a search for the means to fulfill the task, that represent a contribution both to the fields of Motion Design and Science Communication.

Creating motion contents for fulldome, as opposed to flat screen, requires methodologies and conceptualizations that present new challenges and ways of thinking and projecting. To that end, specific methodologies were developed using 3D modeling and animation software. An aspect that could not be overlooked was the immersive sound environment: from sound texture, to sound effects and, of course, narration.

There were eight weeks dedicated to the project, which represented an extra challenge, considering the project's process and methodology: from understanding the concepts, to the validation and creation of new visual languages; from illustration to animation; from representation to infographics; from the technological specificities of immersive sound environments; from exploring the fulldome narrative to the public presentation, discussion and evaluation.

II. CONCLUSION

This partnership has been mutually beneficial: on the one hand, students are presented with a real, motivational challenge, also in terms of skill acquisition (this ESAD post-graduation is a space where practice in real contexts is promoted); on the other hand, the Planetarium gets new contents and new approaches to science communication, that can be used for school visits and in shows for the general public.

As an example of this partnership and the work produced, we present at the IPS Conference 2018 a set of the produced fulldome short films.

Voting systems under the dome : what benefit for education

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BIOGRAPHIES

Educator at the Cité de l'espace for 15 years, then activity supervisor for 1.5 year, and Planetarium programming coordinator since December 2016.

ABSTRACT

After one year using voting systems in the refurbished planetarium, Cité de l'espace will present the main results and knowledge in how voting system has enhanced, or not, the planetarium shows attractivity and visitors involvement. The paper will present the case study of a new educational show using storytelling and the voting system for strategic decisions by the students or for testing their knowledge and will report how this new tool has changed or not the relationship between the lecturer and the visitors.

INTRODUCTION

We have all seen the evolution of technology for the last years. Some of them can be useful for planetarium activities, such as voting systems.

There are many ways of using these systems.

Experiences show that students learn better if there are evaluations of their knowledge.

1/ First, we could use the voting box system for a very simple question :

LIFE Do you believe in life out of the Solar system ?

There is no good or bad answer, it is just an opinion. But to be useful in pedagogy, the vote must use the knowledge or sense of logic of the audience.

2/ For example : (**question / quiz**)

We are now under the sky that we will see tonight, at 11 o'clock, heading north.

3 CONST We can see some of the most famous constellations : the Big Dipper, the Small Dipper and Cassiopeia.

DIURNE If we accelerate the time, we notice that every star moves around this one, which remains always at the same place.

IPS POLAR What is its name ? Please choose among 3 propositions, using the voting box on your right hand.

- The shepherd star ?
- The polar star ?
- The rock star?"

You have 20 seconds to answer, and can change your mind until the end of the vote.

The good answer is the Polar star : it's immobile because aligned with the rotation axis of the Earth, so the polar axis of the Earth. The shepherd star is not a star but the planet Venus.

By using this type of vote during a presentation, the audience becomes active. The playful approach is a way of keeping the public's interest by interacting with him. The most important, if we look for an educational interest, is that the question must give the opportunity to the student to express his position. It must not be just a question of hazard, or just his opinion. This time, there is a good answer, the question mobilize knowledge.

3/ The **pilot mode** is just for fun, for entertainment, leaving the control to the public.

PILOTE MODE SATURN Now you are flying above the rings of Saturn. Please press the buttons as indicated on the dome to control your direction.

As you notice, it is difficult for a group to go in one direction. It is more efficient with one pilot than with 300 !... Anyway, it is funny, but the benefit for education is poor.

[CANCEL VOTE]

4/ Let's come back on Earth, heading South, this time. **CIEL SUD**

With the **Decision vote** we will now try to give the hand to the audience, so that they do not only see a planetarium show, but decide on the subject. For example :

JUPITER SATURN "What planet do you want to visit ?

- Jupiter
- Saturn"

This vote does not use knowledge or sense of logic, it is just a choice, so there is no pedagogic interest.

But it can be expanded to decide the **content level**, depending on the audience.

WHAT SUBJECT "What subject do you want to discover :

- The Moon phases ?

- The seasons on Earth ?
- The birth of stars ?
- The fusion reactions inside the Sun ?
- The Spectroscopy and detection of exoplanets ?”

In this case, the voting system gives the opportunity to customize the show, or to adapt it to the audience : primary school, secondary school…

CIEL NORD

5/ The first system we saw, the “**question vote**” can bring something more. For example, we may ask a question at the beginning of the show, and ask the same question at the end, to see if the public has learned something during the presentation.

The best should be to ask the question a first time, then, later a second time, on the same subject, but by a different way. For example :

IPS POLAR 2 We give the good answer. But later in the show, we go to Venus :

VENUS And ask a new question : “Venus shows different phases.

Venus is :

- A planet ?
- A star ?

The difference between Venus and the Polar Star was discussed earlier, so twice, but by different ways, which is more efficient.

POSITION STL Here, at the Cité de l’espace, we made a choice slightly different for our next planetarium show. It is divided in 5 parts. At the end of each part, we ask a question which deals with it. We invite the children to talk together, debate the answer.

Now we can see the Moon, in front of us, the Earth, just above, and the Sun on the upper left.

WITHOUT SUN Here is the question : “Without the light of the Sun, what would remain visible ?

- Nothing
- The Sun
- The Earth
- The Moon
- The stars”

Here is a short version of 20’’. In our show, we let 45 seconds to the audience to debate and share their points of view. If there are not enough good answers (less than 50%, or 70%), instead of giving the answer, we give a clue :

CLUE FOR SUN “What makes the light ? What is illuminated ?”

Then, we make the same vote a second time. During our tests, we noticed that there was more debate between the children after the clue : they use it to explain their choice to their friends. So in this case, the children use their knowledge, they debate and use logic.

Then, as most of the people better remember what they see than what they ear, we **play the answer**, launch a sequence that shows what would really happen.

SUN OFF

By visualizing the answer, the audience will easily understand, and remember it. The vote becomes more educational because it gives the opportunity to debate on the answer, and is followed by an animation that shows it.

But during our tests, we had a surprise. We thought that there will be more good answers at the second vote than during the first one, thanks to the clue. But it is not the case half of the time. Thanks to some animators who were among the children to listen to the reactions, we understood that the children were influenced by the color of the results. As every answer appears in red, even those who gave a good answer thought it was wrong, and changed it during the second vote. So the explanations made by the animator, the words he uses, are very important.

CIEL NORD

IPS POLAR + ANIM REPONSE

You remember the question about the Polar star ? It would be helpful to complete it with an animation. This time, the vote launches a journey to Venus, and then another one which shows the rotation axis of the Earth pointing toward the Polar star.

We also could imagine to see Earth, Moon and Sun, and propose to the audience : “place the Moon so that we can see a full moon.”

6/ To summarize :

- Tests of knowledge can be useful
- It is better if it gives the opportunity to discuss and debate
- It is better if using knowledge and sense of logic
- It is possible to un-built the wrong representations of children, then rebuilt the knowledge
- It is useful to ask many questions on the same subject, under different ways.

We are just at the beginning of this voting system in our planetarium. Other ways to use it are probably to be discovered. So the next years will be very exciting for that.

Thank you for your attention.

Interactive 360° projection on a sphere at Brussels's planetarium: a case study

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BIOGRAPHY

Champagne Georges

2002 - Master of science in applied physics — Université Libre de Bruxelles

2002 - Today : Technical supervisor — Planetarium of the royal Observatory of Belgium

- Daily maintenance of the audio-visual equipment

2013- Today — Planetarium of the Royal Observatory of Belgium

- Science communicator

Giving lectures about astronomy with a level range varying from for younger children to university grade lessons

ABSTRACT

The planetarium of the Royal Observatory of Belgium made last year the acquisition of a projection sphere (360° projection on a globe).
Located in the center of our exhibition hall, it has become the main attraction for the visitor waiting for the planetarium show to begin.
In this case study, we would like to share the acquired experience we have gained working with this new tool.
We will discuss the requirements needed to make it the favorite attraction of your exhibition hall, from the technical aspects of the implementation to the different usage you can do with it.

INTRODUCTION

The Brussels's planetarium hosts a small exhibition hall (200m²), free of access, mainly to entertain our visitors waiting for the planetarium show to start. This space is naturally dedicated to the astronomy, but not only. Indeed one of our tasks is to promote the visibility of the research done by the three institutes we are linked to: the observatory, the meteorological institute and the Institute for Space Aeronomy.
A lot of questions came along the possibility to renew a part of this exhibition; what should we place, where and how.
We choose to opt for an interactive animated sphere to be the central piece of our exhibition and the goal of this paper is to discuss the way we implemented it.

I. WHY TO CHOOSE A SPHERICAL INTERACTIVE DISPLAY?

I.1. What is a spherical interactive display?

It is a device that can display content on the surface of a sphere. It is achieved by using a computer storing the media files connected to a projection system. This projection can be done from inside the sphere with the projection system (usually below), or from outside with multiple projectors covering the sphere.

I.2. Spherical content and implications

In a world where flat screens are everywhere it is crucial to propose other forms of media to communicate with our public. The sphere can here offer multiple advantages in that way. At first, the format itself implies a central position for the globe, as it should be seen from every direction. It makes it a prime stand for an exhibition and should be highlighted accordingly by the

surroundings. The interest will be triggered by the stunning size of the sphere, the image quality and the interaction capabilities. Then the experience of the visitor will depend of the content itself on the sphere. Good quality content already exists and is free for the main potential topics you can think of in a planetarium.
If you want to create new content the projection format implies to produce the images on a flat screen but to be seen on a dome (i.e. seamless images, resolution near the poles…). Luckily, planetariums use those distortions for their shows and they usually got the tools to produce spherical content. It is even possible to export the planetarium content straight to the sphere. Moreover a lot of content is now easily available for the VR format that can immediately be shown on the sphere (for a group of people).
From a pedagogical point of view the sphere also brings its own advantages. First you can see the entire surface of a planet at once. This gives a better idea of the global appearance and allows to understand the "day-night" cycle or the strange path of satellites on maps. Then complementary explanation on the topic can be displayed on the touchscreen that allows the interaction with the sphere. This part is only accessible by one user at a time but again the centered geometry imposed is wonderful to share information with a group all around the sphere, be it a family with an adult and his children or a school group.

I.3. Interactivity

Interactivity affect the time spend by the visitor and consist on the fun part of the installation. It should not be overlooked.
Of course, there are lots of ways to interact with the sphere and ongoing technologies will offer many more approaches but in this case study, a visitor can interact with the content via a touchscreen, letting him choose the language, the topic wanted and the possibility to rotate the content on the sphere.
Another possibility given here is to play immediately a 360° video on the sphere (i.e. by the mean of a wireless device). This is a very interesting feature as it offers another way of using the projection sphere, this time by a member of the planetarium staff using it as a tool to teach outside the planetarium dome by choosing the content from his/her own library.

II. INSTALLATION

II.1.How to keep maximum impact

As mentioned above the visibility of the sphere is the first concern. The field of view around must be as clear as possible to encourage the sharing experience. In the same time a protection system structure/shield must be set up to ensure the security of the installation. This means risk analysis concerning visitors and the system configuration itself. The size of the sphere itself is obviously the first specification to examine when it is about eye-catching. But it must not be at the cost of a poor image quality. The image quality will be given by the specifications of the projection system used. There are plenty of solutions to face a maximum of situations and you will find one that fits yours easily.
At the Brussels's planetarium, we choose to have a projection system of one projector below the sphere beaming from inside (fig. 1).

Figure 1 - Projector case & sphere

It allowed us to stay within our budget while limiting the maintenance costs.
Having only one projector lowers the risk of a failure but also lowers the luminosity of the picture. The center of exhibition hall was before the installation an available but well-lit space. Occluding all the windows wasn't an option; instead we choose to cover windows with foils letting only a small part of the daylight to shine in (5% & 10% filters). The entire scenography and lighting of our exhibition hall was rebuilt and this added value and style to the whole exhibition.

II.2.Furniture and decoration

The simplest way to ensure the protection of the equipment and the security of the visitors is to keep distances. It is usually done with some furniture or decoration. In this case, we wanted it to allow the visibility from any point of view (which included a staircase). We also wanted it to enhance the sphere and we finally choose it to be a tubular structure forming a big sphere of 3 meters around the projection sphere (fig. 2 & 3).

Figure 2 - front view of the structure

Figure 3 - side view of the structure

To ensure that nobody tries to climb it or enter it the lower and upper parts are covered with plates bended and fixed to the tubular structure (fig.4). The plates are perforated to allow to see through from any point of view.

Figure 4 – Close-up of the side panel of the structure

The projector and the sphere are on a raised floor for cables and the media computer is on a technical space outside the exhibition hall.
The touchscreen is located on the side of the tubular structure on a mount ad hoc.
The space around the projector stays open and thus there was no need to worry about the heat produced by the projector.

III. USAGE

To let the public access the sphere as soon as possible it was clear that we had to rely on already developed content.
As mentioned above, a lot of content is ready to be available at delivery. Historically, the Brussels's planetarium was only teaching astronomy in the planetarium dome in the right line of what was done with our starball. The digital projection opened a window on the visualization of Earth sciences and content gets constantly updated in this way. With a 360° projection sphere we go one step ahead in this direction by offering a selection of content based on astronomy and other Earth sciences. This fits perfectly well with our mission to be the contact between the public and the scientific institutes we belong to.
Even if those content are easy to obtain and implement, to be ready as soon as possible after delivery, it is important to plan ahead the translations if needed. As in our case, with 2 translations to deliver, especially with precise scientific terms, a lot of content can rapidly grow into a big time consuming process for your team.
Producing media for the sphere is rather easy and close to produce content for a dome. The tricky part is to add it to the existing content and to manage the interactivity. This often implies coding and time. Suppliers of sphere develop new software and tools to help with this but anyway it causes hidden work not to be underestimated.

There is always the possibility to just play a video from a library, very useful if the goal is to give a lecture with the sphere. Other opportunities appeared by the firsts months of use. Collaboration with the royal Institute for Space Aeronomy was set up and we added to the content the visualization of their scientific work, connecting the research and the public.
The planetarium of Brussels also hosts various events along the year and the exhibition hall is of multiple uses. In those cases the sphere revealed to be also very useful for promotion even with a single rotating logo.

IV. CONCLUSIONS & FUTURE DEVELOPMENT

About two years after the installation of the sphere at the Brussels's planetarium, we can testimony of the added value of such a sphere. All of our visitors use it and they like it.
The image of the sphere makes great marketing material but do not oversize it or it will be rapidly go out of budget. And a non-negligible part of this budget will and should be used for the surroundings of it.
The pedagogical qualities of such a sphere are obvious and the asymmetric use of the control with one "pilot" and then spectators works remarkably well. Adults use it as a perfect tool to catch the attention of the children and transmit their knowledge.
On the other side, we use it more and more often for groups as we develop workshops and other activities outside the dome.
Future development can be done by adding audio to the media. This could be used to add the trailers of planetarium shows we propose.
We also want to continue the collaboration with the scientific institutes and find ways to reinforce the communication of the work of the scientists to a general audience. We plan to achieve it by upgrading the quality of the data visualization and by implementing a system that will allow the scientists to automatically update the content they produce with the observational data they receive and process.

Astronomy Education in and outside Beijing Planetarium

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BIOGRAPHIES

Dr. Dongni Chen got her PhD in Astrophysics from Shanghai Observatory,CAS in 2006, and has devoted herself in communication and education of Astronomy to the public as staff of Beijing Planetarium since then. She is the deputy director of BP and in charge of all activities related.

ABSTRACT

Astronomy is not a compulsory course in China.Although more and more people realize the importance of Astronomy for students, there still exit kinds of difficulties in teaching astronomy in school.

Beijing Planetarium has focused on solutions to the shortage of teachers, text books and teaching materials of astronomy education. We collaborate with our international colleagues from IAU, NASE, AstroEdu, Universe Awareness and AWB, to promote the education of astronomy both in and outside of Planetarium.

I would like to present what we have done since 2014 and show the situation of astronomy education nowadays in China.

INTRODUCTION

I.1 Astronomy Education in Beijing Planetarium

Beijing Planetarium was built in 1957, is still the unique large Planetarium in mainland of China. Besides two dome theaters , one 3D theater and one 4D theater, BP has around 3000 square meters exhibition. Colorful astronomy education activities are based on these attractive dome shows and exhibitions.

Figure 1 – students are learning to use the astrolabe during summer camp of astronomy

Figure 2 – The volunteer is introducing the astrolabe to family groups in the exhibition “Playing with the stars”

Figure 3– The Foucault pendulum is the most attractive exhibition in BP

Figure 4 – Children are excited when they find animals on the sky map

I.2 Astronomy Education outside Beijing Planetarium

Besides the regular outreach of astronomy based on BP's shows and exhibitions, our mobile planetarium has traveled more than 100000 km in China during the past 10 years and more than 10000 people have chance to reach astronomy outside Beijng Planetarium each year.

Figure 5 – BP's Mobile Planetarium has covered more than 20 provinces in China

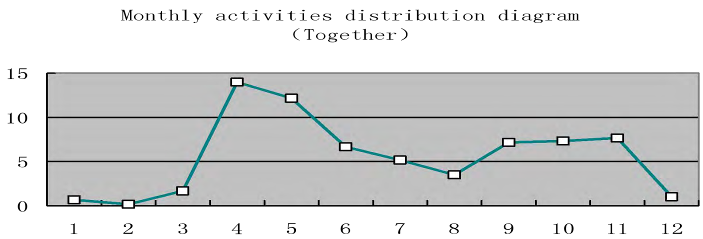

Figure 6 – The statistics of Mobile Planetarium's activity

Figure 7 – BP's Mobile Planetarium goes to a middle school in Liaoning Province,north-east of China

Figure 8 – BP's staff is introducing how to use the telescope while the MP goes to a primary school

Figure 9 – a staff of the mobile planetarium is introducing the Moon to children

II. NASE COURSE IN CHINA

The Network of Astronomy School Education(NASE) was introduce to China in 2012, when the NASE president Dr. Rosa Ros and vice president Beatriz García were attending the 25th IAU GA in Beijing. The NASE course is a wonderful solution for astronomy education outside museums of science and technology and planetarium, since its main object is to teach the teachers in primary and middle school how to "teach astronomy" in their own class. The shortage of astronomy teachers, the text books, the materials and the places could be resolved altogether.

Figure 10&11 – Dr. Ros(Left)and Dr. Garcia(Right) were teaching in NASE course in Beijing Planetarium in 2012

While the NASE course is welcomed by Chinese teachers,there still exit at least three gaps between a normal teacher in school and the NASE course.First of all, the language. Most teachers in primary and middle school could not read the English version of NASE course. Secondly, the content. Though NASE course is mainly compose of 4 lectures and 14 different activities of astronomy, not all the lectures and activities are suitable for Chinese students. Thirdly, the materials. Since all the teachers who are interested in NASE course and would like to bring astronomy into their class are part-time astronomy teachers. There are lot of basic tasks to accomplish before they have time to do anything related to astronomy, they are short of both time and energy.

In order to help teachers who might be a teacher of physics or geography, general science and even arts to take astronomy course easily, we provide the menu of solutions. Firstly, we translate the "14 steps to the universe" into Chinese. So many thanks to all the authors Francis Berthomieu, Alex-andre da Costa, Susana Deustua, Ju-lieta Fierro, Beatriz García, Mary Kay Hemenway, Ricardo Moreno, Jay M. Pasachoff, John Percy, Rosa M. Ros, Magda Stavinschi, they grant China Science and Technology Press permission to publish a Chinese translation.Thus teachers may learn by themselves from the book. Furthermore, we organize the training course of teachers all around China each year, provide the Box of Astronomy which is composed of the illustration menu, all materials used both for students and teachers to the teachers. With the box, the teachers learn how to use the materials and teach their own students according to the menu step by step.

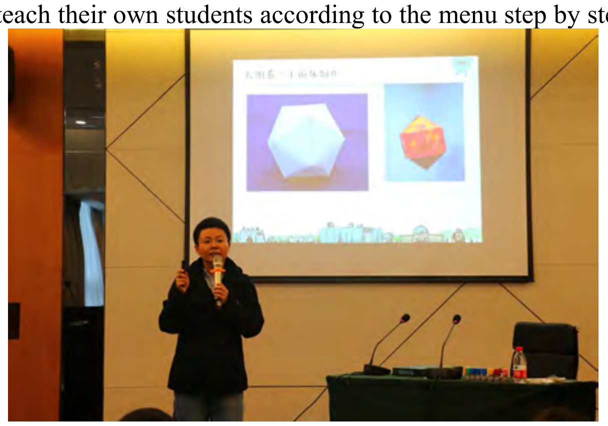

Figure 12 – The author is training the teachers how to play with the solar system using the materials from box of astronomy, FAST,Guizhou Province, China

Figure 13 – The teachers are measuring their own galaxies in the training class very carefully, Nixia Province, China

Figure 14 – The teachers are showing their works so happily, since they just get their visa to all planets in the solar system , FAST,Guizhou Province, China

There have already more than 200 teachers taken in the NASE course in the past 4 years, and the Beijing Planetarium honorably got the Best 2017 NASE course.

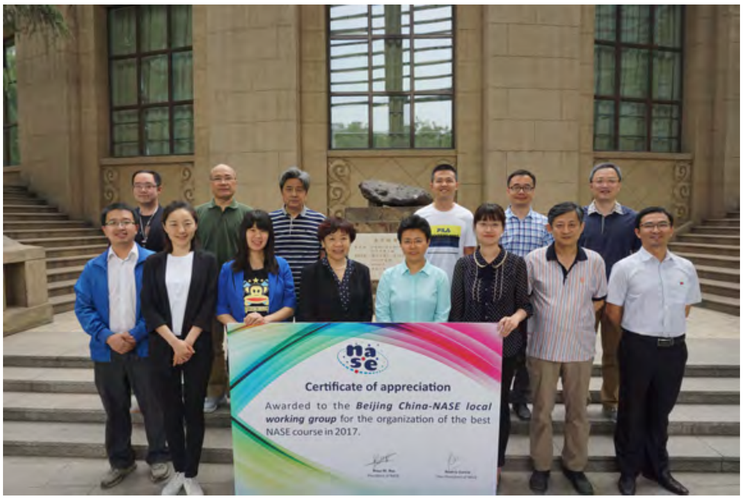

Figure 15 – All the members of the group of Beijing Planetarium for NASE-China

III.FUTURE OF PLANETARIUM IN CHINA

The Shanghai Planetarium has just finished her frame work, while the Nanjing Planetarium has announced her collection of design scheme. More museums of science and technology are rebuilt and most of them having a dome with diameter larger than 15m.

Brighter future! More intense competition! More children interested in universe!

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Toward a definition of the Fuldome Documentary Film through Film Aesthetics

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ABSTRACT

The Fulldome projection is shaping up as a major cultural and educational act as social and economically mature actor, it starts to become a multimedia industry and a correlation to the benefit of global popularization of scientific and to the immersive edutaiment (education through entertainment), multimedia and interdisciplinary. I believe one must go beyond the stage of technological and commercial competition arena, for the benefit of crystallization procedures altogether, and the techniques of making live Planetarium shows, ensuring intermodal optimal operation of planetariums, in fact, to present aesthetic and technical challenges of fulldome documentary film**. (95 words)**

Introduction. Long time after painting, sculpture, photography and film developed along with their medium, a new generation of art has emerged in which digital, electronic, architectural and performative materials have offered new forms for creative expression and experience. One can call that this new spark in film art, the fulldome projection and it medium - no longer composed of only passive materials - now embraces and challenges viewers to work as co-creators of aesthetic experience. This is the reason one can search for a definition of the Fuldome Documentary Film through Film Aesthetics.

Section 1

I.1 **Why Film Aesthetics is useful for us?** Most of the consideration on aesthetics itself poses difficulties because of the ways the term has been used to designate particular objects, judgments, experiences, and values. This difficulty becomes perhaps especially acute with regard to film, where aesthetics is used both in highly polemical and specific contexts but also as a way to more simply denote something with an artistic element. First, any assessment of film aesthetics must contend with the precarious position of aesthetics itself more broadly. Second, and considering this contested relation between aesthetics, beauty, and art, the complex and often conflicting relation of film to art must also be noted.

Of course, the differentiation of an aesthetic of film from film theory or film philosophy is complicated and often well contested. What might be understood as an aesthetic of film extends back almost to the origins of the medium, and much of what we identify as film theory could be understood as having some aesthetic concern, either as a consideration of film as an art or as a part of the realm of the life.

And if considerations of the aesthetics of film confront the novelty of the medium in its early years, then the recent reemergence of the aesthetic in film studies must be seen as an attempt to confront the seeming obsolescence of the medium. In many ways, the consideration of a film aesthetics demonstrates the fissures within the various critical discourses on film, especially, in the present days. The divisions appear between those accounts influenced by figures of recent continental philosophy, those associated with what is often called the "screen" or the "apparatus" theory, and finally those who follow the tradition of analytic philosophy.

I.2 **The Realism in Cinematography.** In planetarium we advocate we present the universe as real as it is seen, drawn, photographed and mainly, filmed. The film was not realistic born in the aesthetic sense of the term. Originally, the film it is just a realistic technique. The first films were, of course, designed as reportages, a form of recording the world as this world could be seen then. We can quote Andre Bazin, who distinguished between "trompe-l'oeil pseudo-realism" and "the real realism we need to express the concrete and essential meaning of the world"(1). At this diegetic level, the realism is essentially a technique, a perceptive realism; meaning, the technique itself must be invisible, in order to permit to objects to be seen and understand, as if they were perceived directly, without cinematic mediation. One can think about a cloning of reality, or, at least, even a true story about reality.

The Diegetic Realism is an aesthetical one only in case of Naturalism. The feature of naturalism is to precisely reduce all aesthetics to a figurative technique. In the case of Realism aesthetics, actually, diegetic Realism is only a necessary but not sufficient condition. We may conclude and say that the evolution of cinema in the digital era could send all the aesthetic concepts of the Basin era to a reconsideration process. The critical approach to the Authors' Program will be able to preside over the new waves in the cinema. As always, Each wave will criticize the previous one.

So far, we can find, wave after wave, and we can quote a \"wrong\", but understandable trend, in the 60s, namely that of continuing to practice the Author cinema/film production. The birth of cinema as an autonomous art is very difficult to specify as a date. Andre Malraux considers it synchronic with the discovery of the cut-out/ *decoupage* itself, both as a technique and as aesthetic value, which brings him a significant function in the history of aesthetics: the Realism. (2).

For now, the production of fulldome documentary films is rather artisanal, exploratory, always dependent on the evolution of the technical means of expression of the fulldome projection (for example, the resolution of the full-length documentaries distributed in 2018 exceeds constantly 4K pixels, 6K and 8K , already). These films, however, are the best possible technical replicas of reality. Now, there is only the problem of crystallizing the concept of fulldome documentary film. Surely, the transfer of fulldome technologies to classical extraction cinema will cause an aesthetic reflux to those who are now practicing the art of the film under digital planetarium or even under iMax installations.

I.3 **The compass for the Search.** Imagine we can define the four cardinal points of the compass needed to search for optimal digital fulldome production and system. The first cardinal point is, of course, the human factor. Even if we use a digital fulldome system optimally, very affordable and able to deliver better performance in the field, the human factor remains decisive' long after major technological problems were resolved. This solution brings into question already, two other points of the Compass: the price and performance of fulldome projection. Therefore, we could say that the fourth cardinal point of the compass imagined would be the multimedia fulldome production industry itself, speaking in plain English: the fulldome films.

With regard to the choice of one of these four cardinal points as North, this is still an open question. I chose the human factor as North of compass in search of a fulldome digital educational system portrait-robot at the beginning of the digital age. A definition of documentary film of this solution will facilitate understanding the fulldome new educational and scientific equipment, namely digital fulldome system optimally. Of course, the justification and promotion of digital fulldome systems, in particular, is related to the production of the fulldome documentary, because these scientific multimedia products are the most sought after vehicles in astronomy and Astronautics.

One of the conclusions of the survey undertaken in 2014 by Maciej Ligowskii, in anticipation and preparation of biennial programme of the International Conference of the International Society of Planetariums/International Planetarium Society (IPS) which was hosted during the period 19-25 June 2016 in Warsaw, is confirming our hypothesis and that the projection of the fulldome is technically and aesthetically, in an era of hybrid and that it is quality oriented towards interdisciplinary and attractive content to several audiences.

II. SECTION II.

II.1 **The Fulldome Documentary – Starter of a New Film Aestethics.** The Fulldome projection is a result of the information and communication technology (ICT) applied as new media, especially in the educational and entertainment institutions (see the OMNIMAX and Imax). It is often found as a way to open museums towards the digital world via the real world and the fulldome projection is a recurring topic of discussion about contemporary role of museum in informing the audience, an audience consisted mainly in visitors interested in media experiences and experiments. After the web 2.0 and social media boom, along with almost permanent access to digital information via portable devices, it appears that we are approaching a new phase of mediated relationships: immersive projection for masses.

The Technologies for entertainment and popularization of science are designed to "deliver" memorable experiences, accessible to more and more audiences. Already historic, some of the advances made to the cinema technology to serve this purpose were centered on designing a larger, brighter and more informative/data full image, meaning, higher resolution in digital slang. Greater brilliance and the resolution bring more realism to the image, while increasing the image size means greater visual impact and an increase in the impression of presence, immersion level, on the subjective and emotional level.

The latest technical advances in the field of cinematographic technologies are related to digital cinema, computed & computerized, using digital video projectors, complex graphics tools and virtual / projected animated images, equipments that tends to replace movie-based projection technologies, but fully experienced and used in the last hundred years. Virtuarium ... a package of hybrid, digital and analog technologies for wide-screen and semi-spherical screen projection is presented in Osaka as World premiere in 1996 and it was conceived primarily for educational astronomy. (3).

The dream of those who develop digital viewing and projection technologies is a future picture characterized of a resolution similar to that of the human eye searching the human reality and a field of vision instantly so that all retinal receptors could be used to receive visual information. The name fulldome could be the generic, general-purpose designation of this type of projection, but for reasons of diversification and distinction in the commercial environment of digital projection systems, fulldome remained only as a general designation of digital planetary projections, experienced since 1983. (4) . The digital video systems made to possibly achieve these viewing and projection performances are very diverse, from personal digital viewers (5), to image walls (see CAVE systems) (6), semispheres and digital projection volumes- domes (7). Simbiotic, since 1995, we add the sound as information and the equipment, from gadgets to serious, professional installations and to those used in the scientific research world, becomes multimedia systems. (8).

Under the pressure of emerging digital technologies, cinema-planetarium fusion began in the eighth decade of the twentieth century a profound transition that had the purpose of diversifying planetary programs beyond astronomy-related topics. In a classic planetarium, you only have to wait until the eyes adjust to the crepuscular light and even in the dark because it is known that only the constellations will be present. The dramatic effect achieved during the natural eye adaptation is immediately rewarded with the association of the second fractions of the media that make up the duration of any surprising event reappeared in many other genres of documentary and artistic films.

Recently, returning to the heavenly vault, to the greatest visual spectacle in the human life, thanks to the visual stars designed by special optical fibers, adaptation to the darkness was no longer imposed on visitors at the entrance to the planetarium. The aesthetic-specific adaptation to lighting has been replaced by adaptation to projection elements of interest.

II.2 **Planetariums and the Film**. Although, in the technological and media confrontation of the 70s, planetariums have been labeled as "cultural dinosaurs", the planets have recently turned from arid astronomical conference rooms into hybrid multimedia arenas, and have overcome ancient astronomy information.

The Aesthetics and the communication history can be described and rewritten as a history of grafical user interfaces that delivers information increasingly with sensorial realism to more sensory receptors physically or even virtually online. (9). From print to radio and then to video, the purpose of technological improvements inside the media was to make them more resemblance to human abilities to communicate and to receive the world around them, especially. In the case of visual technologies, the resemblance consists in the "demand for screens that is as close as possible to the whole human field of view" (10), the only constant aspect of the documentary film equation of educational astronomy, especially in the planetarium, in this case and his audience.

Returning to aesthetics, as F. Beau, P. Dubois and G. Leblanc have pointed out, "the latest technologies do not, in fact, ever represent anything other than reactivating some very old representation issues.". Consequently, "it is clear that we are witnessing an examination of the images and of the devices or of forms of expressing what they feel as "new technologies", one must analyse this process using historical treatment, articulated according to the forms of representation" (11).

Indeed, as Andre Bazin, often quoted, as Vincent Pinel did, in his preface by Laurence Alfonsi, seem to regard as a natural evolution of the cinema this tendency towards a single idea, the one that lead to have on film a perfect reproduction of reality. Alfonsi, therefore, called it *total cinema*. This phrase is, in fact, never defined in the book, although in the case of the cinema, if this is its function, then the ideal goal would be "the total immersion of the public in the film" (12). In short, this unique, theoretically design of cinema is based mainly on its reception mode, which is retained globally and not due to its many curiosities and the reception mode that has today a correspondent in practice called the fulldome projection and the fulldome documentary film or Imax films.

The entire economy of knowledge, with all its efforts, is revealing the world in the form of a staircase on which we climb to the intelligible, from observation to the modelling, simulation, each foot would be a circumscribing, a reducibility, a didactic simulation controlled by means of a media product: fulldome documentary film. The challenges and solutions in search of exploring fulldome systems must always be reported to the human perception and the Visual information,-in theory, film aesthetics-, resolution beyond the temptations to facilitate the marketing and technical compromises made to the always fashionable. This definition will be adapted to the state of the course, you will learn the market of producers of equipment, all dependent on Planetarium, looking for optimal Planetarium, called left-handed by commercials, cutting-edge Planetarium.

III. Conclusion. The sense of presence, of immersiveness, it would be the first form of audience impact fulldome film and first form of information that one can transmit through this new kind of film, therefore, we can consider the sensation of presence in immersive as an idea-main batter of fulldome film sequence. It seems that everything in the Planetarium is seeking after the applied fulldome type technical and cinematic production solutions. The Cinema specialists can use these analyses for 'weighing' the use of cinematographic means in the context of specific challenge brought about by the application of immersive fulldome multimedia productions.These productions excels in audience virtual transportation through the temporary recalibration of presence sensation, insisting on telepresence as a form of attention getting process towards content of information contained in the multimedia products.

Given the novelty of the concept, we dare to say that the cinema people are somewhat familiar with the film and fulldome paradigms even less with artistic, cultural exploitation of this new film, with fulldome documentary film. Without informed filmmakers, the audiences and the scientific mediators of the Planetarium would be a mere prey to the producers of multimedia content open to compromises in favour of trade handling than informing using fulldome documentaries.

The main concern for the demonstration study exploring digital fulldome projector systems, and for the most suitable means for research of this task with all the interdisciplinary implications takes place in a live manner, atypically, even during the evolution of these digital projection systems, and in conjunction with an operating procedure which looks more like a process of testing on a sample than with a service in the sense of using a good professional technical user guide.

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Non Formal Education for Schools Under the Dome

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ABSTRACT

In 2016 we started a thorough analysis of the Porto Planetarium educational offer, which revealed the necessity to think more in depth on how to potentiate formal education in our non-formal education setting. As a result, we started producing additional fulldome contents in the specific context of the formal school curricular contents and goals. This paper relates to an educational module made up from a live fulldome presentation, linking its contents to the 10th grade Biology-Geology curriculum and noting how the planetarium presentation is of added value.

I. THE PORTO PLANETARIUM – CIÊNCIA VIVA CENTRE

The Porto Planetarium (hereafter Planetarium) completes 20 years in 2018. It was created in a very specific environment, built from the outset so that the creation of scientific knowledge in astronomy and astrophysics (A&A) lives in close connection to the promotion of scientific culture and the dissemination of knowledge and attitudes, especially to young people. It is still operated within this context, being run by Centre for Astrophysics of the University of Porto (CAUP) on behalf of the University of Porto. CAUP is also the host institution of Instituto de Astrofísica e Ciências do Espaço (IA), the largest Portuguese research centre in A&A, which scientifically supervises the Planetarium activities.

The Planetarium is a member of the Network of Ciência Viva Centres. This is a network of twenty science centres in Portugal, led by Ciência Viva, the National Agency for the promotion of initiatives for the public awareness of science and technology in Portugal (Rede de Centros Ciência Viva 2018). The network mission is to promote an active citizenship based on scientific knowledge.

From June 2014 to June 2015 major overhaul works were carried out under the dome, with the installation of a new dome screen, the implementation of a unidirectional seating plan and the installation of a RSA Cosmos ISS 2C 3K digital projection system running SkyExplorer, bringing the Planetarium into the digital era.

At the reopening, in June 2015, we debuted into the licensed realm of fulldome films with “Life – a cosmic story”, by California Academy of Sciences. This was a move designed to start expanding our education offer beyond A&A, with Biology and Geology in mind and their connection to A&A in the wider context of Astrobiology.

II. SCIENCE COMMUNICATION, OUTEREACH AND TEACHING

Science communication, outreach and teaching are different concepts, worthwhile exploring here.

II.1 Science Communication and Outreach

Science outreach is the dissemination of knowledge and scientific skills for an audience that adheres voluntarily to the dissemination activities (Bueno, 2010; Crato, 2016; Fernandes, 2011). For these authors, science outreach and science communication are separate concepts, with the latter emerging as the dissemination of contents between peers. Such notion is not, however, consensual, as seen in Lewenstein (2003) and in Burns, O'Connor & Stocklmayer (2003).

Science outreach aims at a captivating approach towards the communication of scientific knowledge, giving particular attention to the understanding of concepts and not being limited to conveying scientific facts, always without sacrificing scientific rigour. As such, outreach has a key role in captivating the public interest in science and promoting scientific literacy. It informs the public about actual and important scientific subjects, it reveals sources and promotes taking pleasure in knowledge. It shows science as another human creation which, as such, is part of our everyday lives and of our culture.

Science outreach does not replace science education, however the particular interest of science outreach in simplicity and in provoking a feeling of wonder can become a starting point for moments of science education. In truth, one of the most important causes for educational underachievement resides in the lack of an emotional connection between pupils and curricular contents, leading to a lack of motivation to learn them. Models of science outreach may bring an added value in this regard.

II.2 Teaching and education

While often used indistinctly, the concepts of teaching and education enclose paradigmatic differences that make then even incompatible.

The use of the concept of education in detriment of the concept of teaching, relies on the assumption that one of the school missions is, beyond teaching, educating. The idea that a teacher should only be concerned with the act of teaching is, for some authors, very reductionist. More than delineating didactic sequences for the understanding of knowledge, the school thinks about the mobilization of knowledge and skills developed by pupils, as well as on the system of values.

Science education (Crato, 2016), as all formal teaching, is an organized process, with programs (and/or curricular goals) and with moments of formal evaluation that contribute decisively for obtaining a certification.
Given its nature and the amount of time dedicated to it, science education is the largest contributer for scientific literacy amongst pupils.

While outreach is able to choose the themes in which it wants to captivate the public interest, even if only occasionally and in a dispersed fashion, such is not an option for science education. While for outreach to awake for the pleasure in knowledge may be enough, for education the goal is the positive apreciation of an whole program, including the diversity of themes it may include and, most importantly, the mobilization of knowledge and skills.

Using an example from Physics or Chemistry: while for an outreach comunicator a set of physics/chemistry “magic” may be enough to fullfill the objetives, for an educator the “magic” is just the beginning of the process.

The most used distinction between formal, informal and non-formal teaching appears with Maarschalk (1988). Formal teaching is highly structured, it takes place at schools and universities, following a predetermined program that is similar for all students of that school level. Non-formal teaching occurs outside the schools, in places like museums, science centres and other institutions that organize training initiatives. This type of teaching is developed according to the wishes of the participants. Finally, informal teaching occurs spontaneously on a daily basis, from non-programmed experiences, such as conversations and other occasional social interactions. Some authors, like Scott (2016), do not distinguish between non-formal and informal teaching, labelling as informal all learning taking place outside of a school context.

III. SCIENCE EDUCATION AT THE PORTO PLANETARIUM

Astronomy is a subject present in the Portuguese formal education from the very early school years.

Curricular guidelines for pre-school education (3 to 5 year old children) allow for Astronomy to be tackled within the “world knowledge” area content. It firstly attains special relevance on the 3rd grade (8 and 9 year old children), by having a dedicated chapter on Celestial Objects within the “Estudo do Meio” (Study of our Surroundings) curricular discipline. From here onwards, while present in the curricula of all grades, it is dispersed through different curricular disciplines, featuring most prominently in the 7th grade (12/13 year olds) “Physical and Chemical Sciences” discipline and in the 8th grade (13/14 year olds) “Natural Sciences” discipline.

School groups represent around 70% of the total number of visitors to the Planetarium. School teachers are the driving force behind those visits, their motivation resulting from the possibility of tackling, at the Planetarium, specific curricular goals that are more difficult to work in the classroom.

Within this framework, during the 2016/2017 school year, we have analysed our educational materials (own and licensed from others) and produced additional fulldome contents in the specific context of the formal school curricular contents and goals. As a result, the whole Planetarium program for schools was completely reorganized in order to provide a true non formal educational program that complements classroom work carried out at the schools.

We identified an opportunity in the context of the 10th grade Biology and Geology (BG10) curriculum. The Planetarium is licensed to show the fulldome movie “Life - a cosmic story” (produced by the California Academy of Sciences), whose subject is strongly related to that curriculum. To enhance the relevance of a planetarium show specific for the BG10 subject, after “Life” we present a 13 minute long live module, produced with RSA Cosmos’ SkyExplorer 4, with sequences that, despite being associated to astronomy, were chosen due to their relevance for the BG10 curriculum.

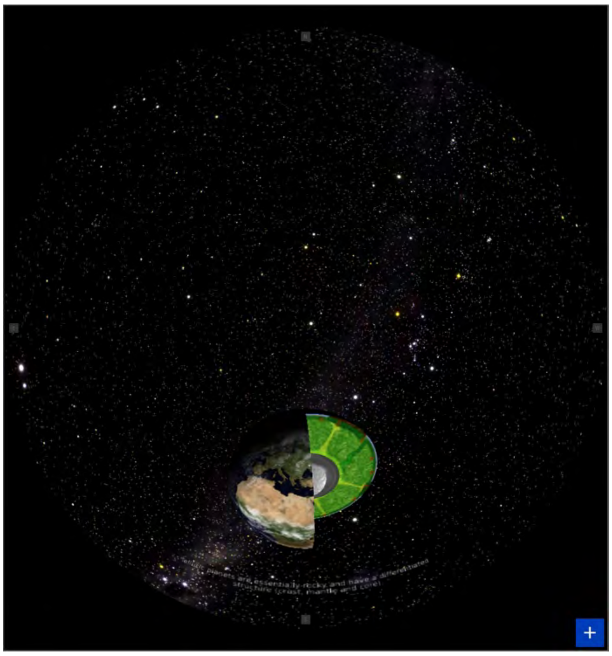

Figure 1: Cutting a slice through the Earth showing a model of its interior.

Figure 2: The Orion Nebula star forming region.

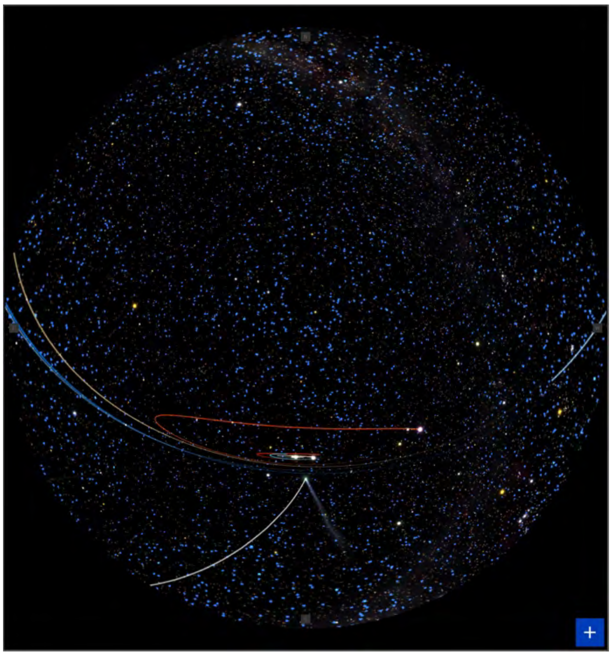

Figure 3: Returning from the Oort Cloud, to follow a comet to the inner solar system.

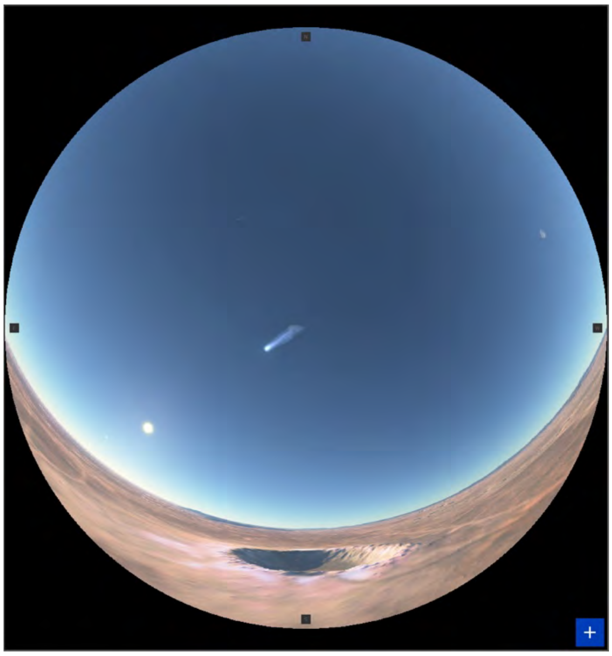

Figure 4: A comet as seen from near Meteor Crater.

Produced by Porto Planetarium with RSA Cosmos SkyExplorer 4.

We start from the northern hemisphere winter sky, focusing our attention on the Orion and Taurus constellations as home to important star and planet formation regions. Lifting off from the Earth, the attention is focused on the Earth/Moon system and from there we move to a general view of the Solar System. We visit the remaining telluric planets, reach out to the asteroid belt and pay a visit to the giant planets. We proceed to the Kuiper belt and to the Oort cloud. We then start following a comet through the inner Solar System and finally return to Earth to witness a meteor shower and see the result of a significant impact on our planet's surface.

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The Immersive Classroom

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Abstract

For generations the planetarium has been the go to place for stargazers of any age to observe the vast tapestry of thousands of stars that could otherwise only be seen in the most remote areas far from city lights. Over time as technology in the planetarium improved we began to offer our guests virtual trips to alien planets and distant galaxies utilizing what we all now know as full dome video technology. The planetarium has always been a gateway to astronomy, but I believe it has become more than that. It is the most advanced immersive classroom, a place where people can come to learn just about anything and feel as though they are there. The whole "the sky is the limit" just got a whole new meaning when it comes to the immersive classroom. In this talk I will demonstrate the many ways we have produced live planetarium experiences in such topics ranging from history and cultural studies, earth and biological sciences, and so much more.

Introduction

For generations the planetarium has been the go to place for stargazers of any age to observe the vast tapestry of thousands of stars that could otherwise only be seen in the most remote areas far from city lights. Over time as technology in the planetarium improved we began to offer our guests virtual trips to alien planets and distant galaxies utilizing technology from slide projectors to modern day high definition digital systems. The planetarium has always been a gateway to astronomy, but in the last few decades I believe it has become more than that. It is the most advanced immersive classroom, a place where people can come to learn about anything from travelling to an ancient temple, travelling through the body, under the ocean, or visiting a remote observatory. The whole "the sky is the limit" just got a whole new meaning when it comes to the immersive classroom.

The Immersive Classroom

Planetarians have been known to enter the field from all walks of life such as music, art, history, and so much more. My personal interests run the gamut from science, history, biology, music, and cars, to list a few. I have also been interested in photography and after purchasing a fisheye lens I loved the idea of capturing real time images of locales that I could share in the planetarium. Implementing virtual reality experiences in the planetarium can allow visitors to explore almost anywhere they would want to go. When we installed our full dome video system years ago we were very excited to work with SCISS and utilize their Uniview software. Using our new capabilities we could anywhere in real time, which fit well in our philosophy of presenting completely live and interactive programs for which we pride ourselves on in the planetarium field. Now we could take attendees on a trip to Mars, fly out of our home galaxy, or take a trip through the human body. The immersive classroom was beginning to take shape.

You can have all the wizbang technology at your disposal but without the right teacher the classroom (or planetarium) can only go so far. I find that the most effective educators can teach as though they are storytellers, connecting our emotions to the lesson we are learning and utilizing the dome for this purpose is very effective. Being inside a space that engulfs you with what you're learning just cannot be achieved in a normal classroom environment. I always enjoy including myself in my fulldome images because the students or guests can connect with the presenter as if they were standing there themselves. In the modern planetarium the teacher can do more than just tell the story of the night sky, they can impart the story of our Universe. The planetarium, though not as sleek as a Delorean, is a time machine, taking our audience back to any time period. One of our more recent shows discusses the fate of the dinosaurs and we transports our guests to the Hell Creek Formation in modern day Montana where they discover the K-PG boundary. Being immersed in this barren landscape allows us to tell the story behind the science of how we know that the dinosaurs disappeared around 65 million years (well most of them, birds are dinosaurs too!). We then take our time machine into Earth orbit and overlay several paleontological maps created by Dr. Ron Blakey that show the plate tectonic activity from the Triassic and Createcuous periods to modern day and how much our Earth's surface has changed over time. Sure this same thing could be done in a textbook or video, however the planetarium engages the audience in a way that leaves a lasting impression.

The immersive classroom is not limited to just science either. Recently we created a series of shows in conjunction with the Humanities Department at Seminole State College of Florida. One focused on the American Civil War, the other was about Native American history and astronomy. We travelled to several locations in the United States to capture special fisheye images that we then imported into Uniview utilizing the fisheye image uploader. As a result we were able showcase various areas: Gettysburg, the Appomattox courthouse, Chaco Canyon and Big Horn Medicine Wheel. Being surrounded by these beautiful landscapes connects the audience as if they were actually on tour in real life. Adding authentic sound effects recorded at the sites can also enhance the sensory depth of the virtual reality experience. Of course sometimes it may prove difficult to travel, however through partnerships, funding could be available for such projects. Perhaps there is a location nearby that teachers are unable to take their students to but can be done virtually in your immersive classroom. You could capture fisheye images and record sound and then provide those students with a virtual field trip in your planetarium. These partnerships strengthen the need for a planetarium in the local community. It also removes the notion that all a planetarium can do is view the stars. Teachers are always looking for ways to enhance learning in various fields of learning. The planetarium is just that enhancement. Any way the planetarium can increase its position in the community is a good thing! Below you will see some examples of images I have taken and apply to our dome.

The Burgess Shale, a world heritage site for exquisite fossil specimens from the Cambrian Period.

Grovesnor Arch in Utah. Great example of showing geological events in the dome.

Temple of Kukulkan in the Mayan City of Chich'en Itza.

360 Panorama of Pueblo Banito in Chaco Canyon New Mexico. 360 Panoramas can be uploaded using various software like World Viewer to display 360 degree images in the dome giving a truly immersive experience.

The ALAM Radio Observatory in Chile.

Conclusion

There are few places where people can go that showcase the grandeur of our Universe other than the planetarium. In many ways we get to be like the Magic School Bus, taking our audience on a grand adventure to incredible places, and with the aid of a knowledgeable educator we are able to give them an experience they will never forget. So…Mr/Mrs teacher, where are we going to explore in class today?

Zagreb planetarium – historical view and how it works

Zvonimir Drvar, *Technical Museum Nikola Tesla, Savska cesta 18, Zagreb, Croatia*

E-mail: zvonimir.drvar@tmnt.hr

BIOGRAPHY

Zvonimir Drvar works as a curator at department of Astronomy and astronautics and is also Head of planetarium. Earlier, he worked as an educator in Zagreb astronomical observatory. He specializes in education and also organizes scientific lectures and workshops.

ABSTRACT

Zagreb Planetarium is situated in Technical Museum Nikola Tesla in the center of Zagreb, Croatia. It is in function since 1965, and there is almost no day when planetarium projector isn't in use. Projector ZKP-1 was made by Carl Zeiss in Jena, East Germany, in 1963 and it is probably one of the oldest planetaria in Europe still in use. Nowadays, shows are going daily, except Mondays when museum is closed for public. More than 30 000 visitors pass the planetarium during the year, most of them are school groups and individual visitors.

INTRODUCTION

Zagreb planetarium in Croatia is part of Technical museum Nikola Tesla and its department of Astronomy and astronautics. Museum was opened for public in 1963 and was immediately given a new planetarium. Originally, the planetarium projector was donated by the City of Zagreb to the astronomical observatory but due to the lack of space there, Major of Zagreb made a decision that new planetarium dome should be built inside Technical museum. The works on dome building lasted for two years and were finished in early 1965. Soon after, new planetarium projector ZKP-1, was installed in the dome and planetarium was opened for public with 1st show given on May 18th, 1965.

Figure 1 – Technical museum Nikola Tesla

Figure 2 – Planetarium dome

I. SECTION 1

Historical view

History of Zagreb planetarium can be divided in two parts – 1st being from its opening to 1995 and second from 1996 until modern days. What divides these two parts is the reconstruction of the dome from November 1995 to May 1996. Works included in reconstruction were installation of air-conditioning system, perforation of the dome wall due to necessary exit input and insertion of a new CD player with audio amplifier.

According to museum propositions, only one person/employee at the time can be Head of planetarium. First one was professor Leo Randic, astronomer and geodesist who worked in planetarium from 1965 to 1968. After him, the Head of planetarium became Branka Romer. From 1972 to 2016 Head of planetarium was Ante Radonic and Zvonimir Drvar succeeded this position in 2017.

II. SECTION II

How it works

Nowadays, shows in planetarium go on almost every day throughout year except Mondays. From April to June and in October, planetarium records most groups; there can even be 10 shows per day. During summer and winter holidays number of groups decreases while number of individual visitors increases. In year 2017 planetarium recorded 30 000 visits and 800 shows.

One show lasts between 30 and 40 minutes. During that time light slowly turns off for 10 minutes because eyes need to adopt to complete darkness, while the audience listens the music. When the dome becomes completely dark, about 2 500 stars can be seen on dome's inner surface. During presentation, accent is put on starry sky that can be seen in particular night from Zagreb. Planets, Sun, Moon, Milky Way and ecliptic and equatorial planes are also shown in planetarium. Images that represent some significant constellations are also shown. This part usually lasts approximately 20 minutes after which the light slowly turns on for about 3 minutes.

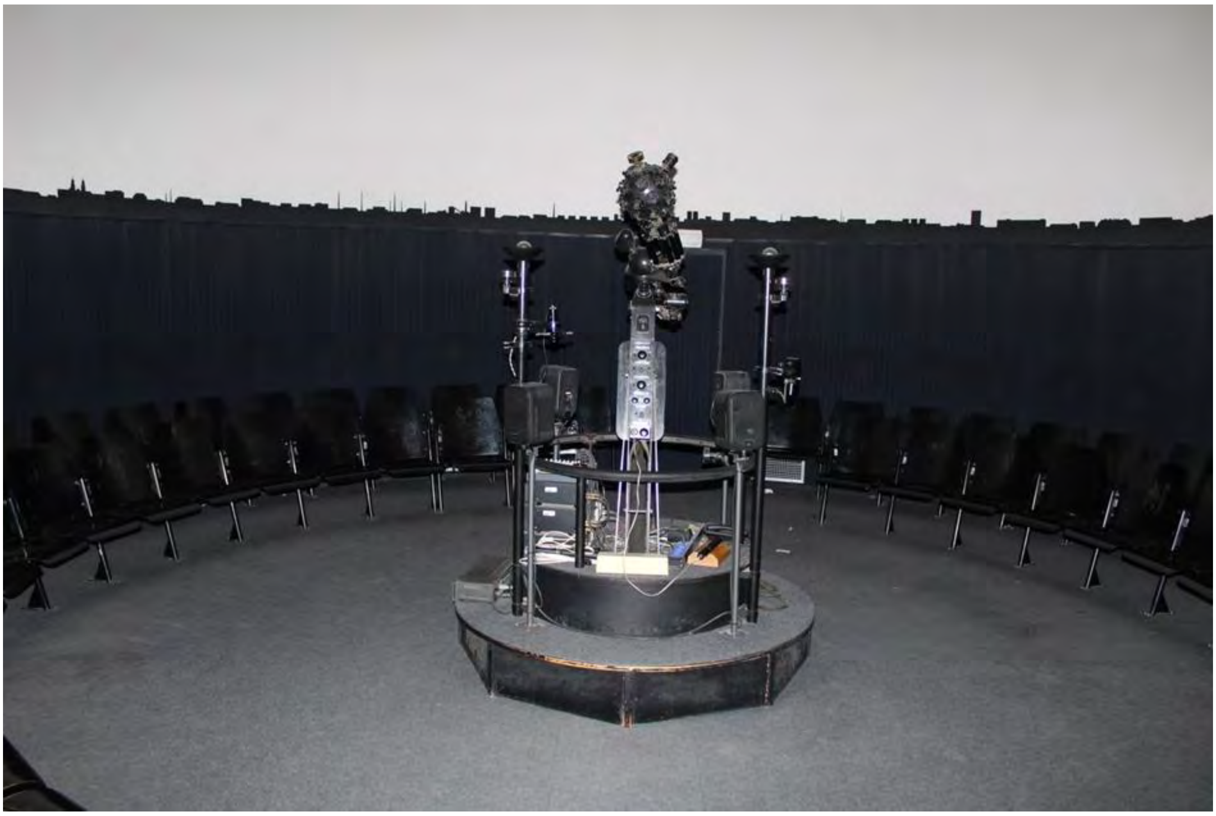

Figure 3 – Planetarium dome from inside

Except usual shows there are also shows that are run for special occasions such as shows that introduce new season on equinoxes or solstices, shows during World space week, Museum Night, St. Valentine's day and so on. Such shows often last more than one hour and are always attended. Planetarium dome also hosts concerts due to acoustic interior and some game shows such as „Terrible creations".

Future plans include removal of current seats and insertion of new seats which would allow spectators to watch more directly above rather than towards projector. We also intend to replace current planetarium projector with a new Skymaster ZKP-4 since the existing one is more than 50 years in use.

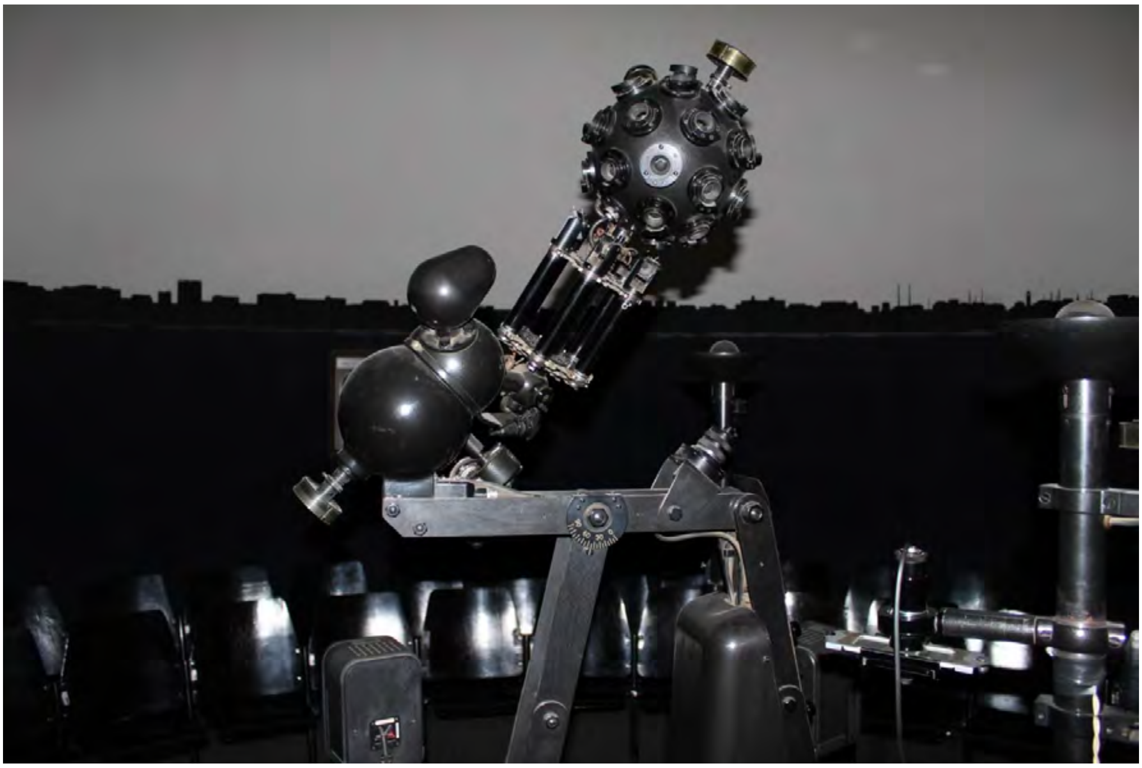

Figure 4 – Planetarium projector ZKP-1

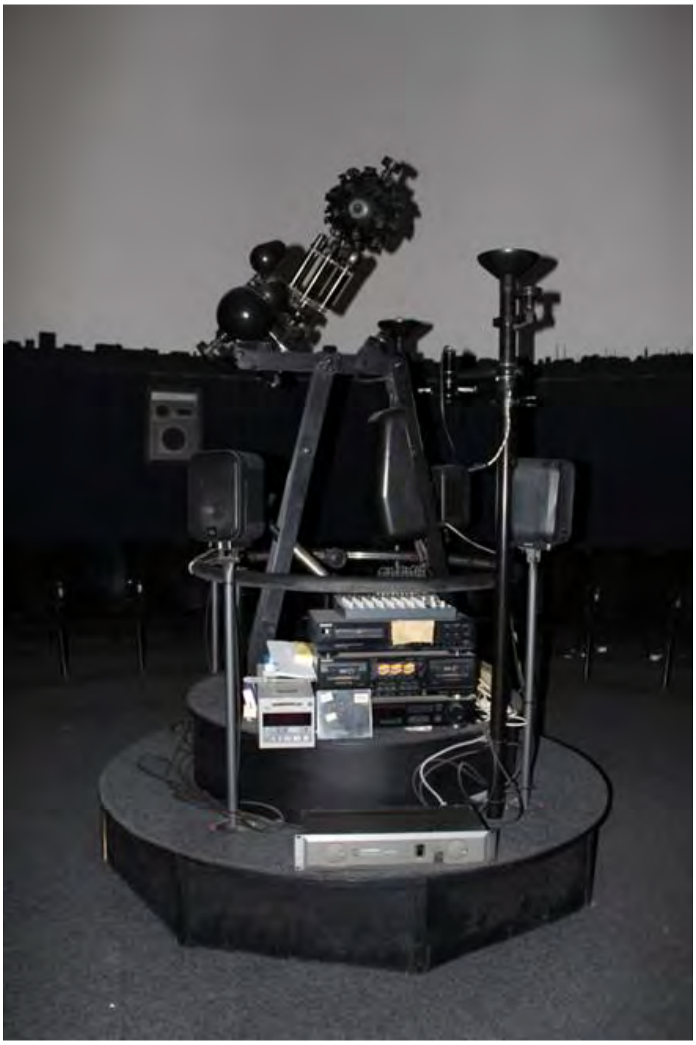

Figure 5 – Side view of the projector

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Bringing Scientific Discoveries to the Dome: A Journey to the Edge of the Pinwheel

Dr. Patrick Durrell, *CosmoQuest and Ward Beecher Planetarium*
Dr. John Feldmeier, *Ward Beecher Planetarium*
Dr. Pamela Gay, *Astronomical Society of the Pacific and CosmoQuest*
Curt Spivey, *Ward Beecher Planetarium*
Tiffany Stone Wolbrecht, *Ward Beecher Planetarium*
Annie Wilson, *CosmoQuest and Ward Beecher Planetarium*
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BIOGRAPHIES

Dr. Patrick Durrell is an astronomer and Distinguished Professor in the Department of Physics & Astronomy, and is also the Director of the Ward Beecher Planetarium. Dr. Durrell studies the formation of galaxies through photometric studies of stars and globular star clusters both within and outside of galaxies (intracluster stars). He is also involved in science outreach through the Ward Beecher Planetarium and CosmoQuest.

Dr. John Feldmeier is an associate professor in the Department of Physics and Astronomy at Youngstown State University. An observational astronomer, John studies galaxies, galaxy clusters, and the stars between the galaxies. He also works in the field of astronomy education research and is interested in applying new astronomy education techniques to the classroom.

Dr. Pamela Gay is an astronomer, educator, podcaster, and writer, best known for her work in astronomical podcasting and citizen science astronomy projects. She is the Director of Technology and Citizen Science for the Astronomical Society of the Pacific. Her research interests include analysis of astronomy data and examining the impact of citizen science initiatives.

Curt Spivey is the Planetarium Engineer and planetarium show producer at Ward Beecher Planetarium. A native of Columbus, Curt graduated from Ohio State in 1992 with a degree in Astronomy. Curt has worked in several planetariums over the last 25 years, joining the Ward Beecher crew in 2009.

Tiffany Stone Wolbrecht is the Planetarium Lecturer at Ward Beecher Planetarium at Youngstown State University where she coordinates all programs for the over 15,000 annual public and school group guests. She also produces live planetarium content for audiences of all ages. She also advocates for Cosmosquest, an online citizen science research center.

Annie Wilson is a show producer at Ward Beecher Planetarium where she has worked on fulldome productions including *Cosmic Castaways.* Annie also produces content for Cosmoquest, an online citizen science research center.

ABSTRACT

This project brings the latest Hubble Space Telescope research of M101, aka the Pinwheel Galaxy, to life on the dome. The diverse and talented team at the Ward Beecher Planetarium is producing their second full length installment, taking the latest in astronomy research and showcasing it in a documentary-style fulldome (and flat screen) show that will be made available to all planetariums at no cost. The Stars of

M101: Exploring an Immense Spiral will combine cutting-edge astronomy research with a thoughtful, NGSS-aligned script and a combination of stunning simulations and animation.

INTRODUCTION

A pair of full-dome planetarium shows are in production based on recent Hubble research of the Pinwheel Galaxy M101. In both shows, audiences will learn about the features and phenomena that exist in the outer regions of spiral galaxies like M101. The two shows will mirror each other visually with one written as a straight science narrative and the other conveying the science through a fictional narrative. These shows are being produced under a grant and both fulldome and flat screen versions will be made available for planetariums around the world at no cost.

I. Overview

A pair of full-dome planetarium shows are in production based on recent Hubble research of the Pinwheel Galaxy M101. In both shows, audiences will learn about the features and phenomena that exist in the outer regions of spiral galaxies like M101. The two shows will mirror each other visually with one written as a straight science narrative and the other conveying the science through a fictional narrative. These shows are being produced under a grant and both fulldome and flat screen versions will be made available for planetariums around the world at no cost.

The Non-fiction narrative, titled “Stars of M101: Exploring an Immense Spiral” will take the audience on a tour through the structure of a large spiral galaxy. Topics include companion galaxies, open clusters, and star formation. The Fictional narrative, titled “Journey Out of the Pinwheel” covers the same topics in less detail and in told from the perspectives of two ship pilots taking turns out of stasis to observe their journey. This script is written by Pamela Gay based on notes by award winning writer P.G.Holyfield.

Figure 1 – M101, the Pinwheel Galaxy

II. Potential Reach

It is our hope to reach larger audiences, in domes big and small and regardless of budgets or equipment, so flat screen versions of the show will be made available as well. There are also tentative plans to provide a Spanish-language version of the non-fiction show. Both shows should be available in early 2019.

Ward Beecher Planetarium staff is proud for the opportunity to produce another fulldome show on new scientific discoveries and at no cost to other facilities. For information questions on distribution, visit our website at wbplanetarium.org/production.

“The relationship between music and science, a pathway to discover number, sound and wavelength reciprocity”

Simonetta Ercoli, *“StarLight… a handy planetarium” Association*
Email: mirusi7678@gmail.com

BIOGRAPHY

Simonetta Ercoli was borned in Perugia, Italy on the 25th of August 1951. Her degrees are in Biology and in Natural Science. She was a Science teacher and tought Astronomy at the secondary school until her retired. She was the responsabile of Ignazio Danti Planetarium, in Perugia, since 2003 until 20013.

ABSTRACT

Insert abstract here (approximately 100 words). Body text should be 10 points Times Roman. The project aimed at creating musical compositions devoted to each planet of our Solar System, following the path of Johannes Kepler in his Harmonices Mundi treatise. Starting from Pythagorean ideas about the music of the spheres then transferring this concept to the rules governing planetary motion, Kepler formulated the third law of planetary movements. The project consisted of an event for each of the planets known at the time where scientific aspects and harmonies tracked down by Kepler were explained, after which the corresponding piece was played on the piano. At the end of the project, a concert was organized with all pieces and with the background projection of the basic scientific work. This work is, adopted for two kinds of workshops at schools.

INTRODUCTION

Music is rooted in our auditory, cognitive and motor functions. The physical nature of sound and its exquisitely mathematical characteristics manages to "couple" the mental and emotional dimensions and bring them to the top, for this reason it’s study has played an important role since ancient times. The Pythagorean model remained for a long time a point of reference for cosmology, so much so that Kepler also referred to the Pythagorean and Platonic idea of the universe, when he undertook his work to confirm if the scheme of the universe and its parts could be expressed in numerical and geometric relationships. His search for the explanation of the motions of the solar system planets started from the heliocentric model of the Copernican system, with the analysis of some inconsistencies present, such as the permanence of the epicycles, which did not offer a correct answer to the anomalous path of the planets around the Sun.

I. SECTION 1

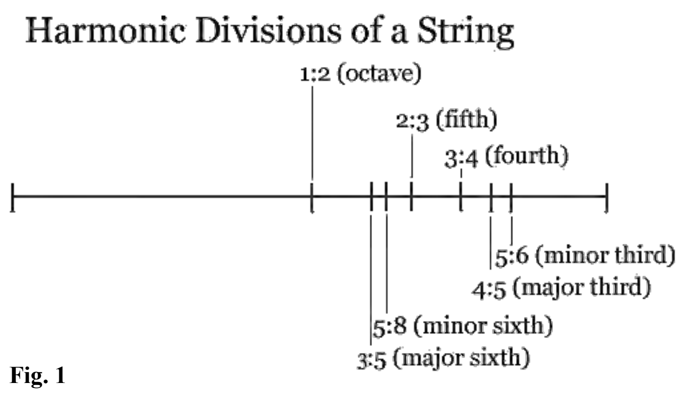

Fig. 1

These are the mathematical ratios for creating the intervals that Kepler finds by experiment are both consonant with respect to the whole string and with each other.

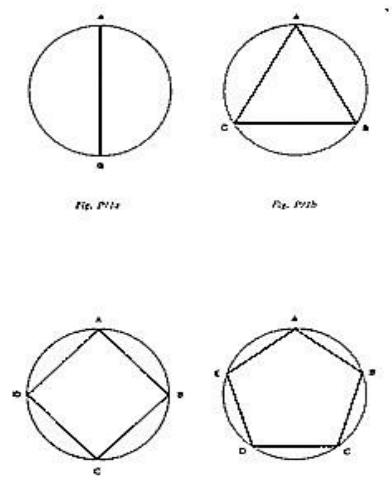

Fig. 2

Kepler sought all the consonances of a monochord even on a circle.

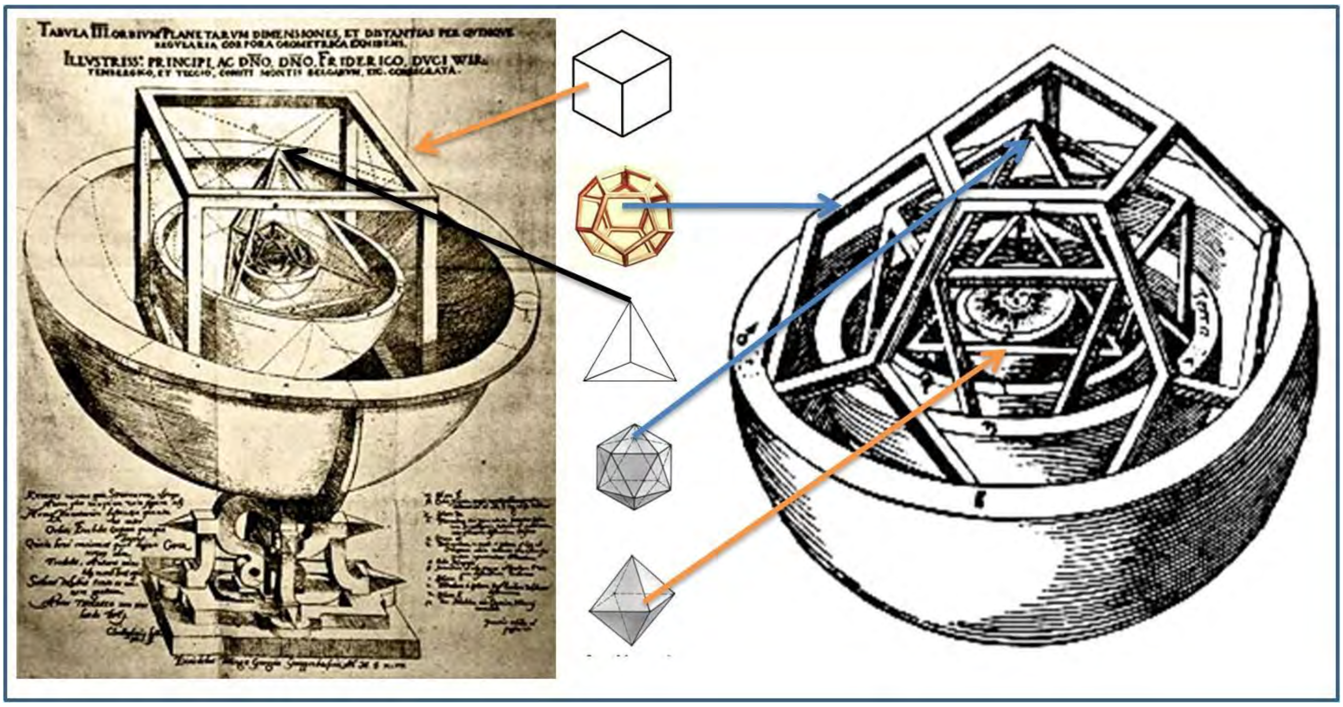

Fig. 3 *Kepler's polyhedron model of the Solar System*

Apparent daily motions		Harmonies closer to the accuracy of each planet		
Planet position	*Minutes and seconds*	*Minutes and seconds*	*Ratio*	*Interval*
Saturn A Saturn P	01'46" 02'15"	01'48" 02'15"	4/5	Third major
Jupiter A Jupiter P	04'30" 05'30"	04'35" 05'30"	5/6	Third minor
Mars A Mars P	26'14" 38'01"	25'21" 38'01"	2/3	Fifth
Earth A Earth P	57'3" 61'18"	57'28" 61'18"	15/16	Semitone
Venus A Venus P	94'50" 97'37"	94'50" 98'47"	24/25	Diesis
Mercury A Mercury P	164'0" 384'0"	164'0" 394'0"	5/12	Octava + Third minor

Fig. 4 *Comparison the ratio found between the amplitudes of the orbital arcs traveled by each planet in the most static moments with those of musical intervals.*

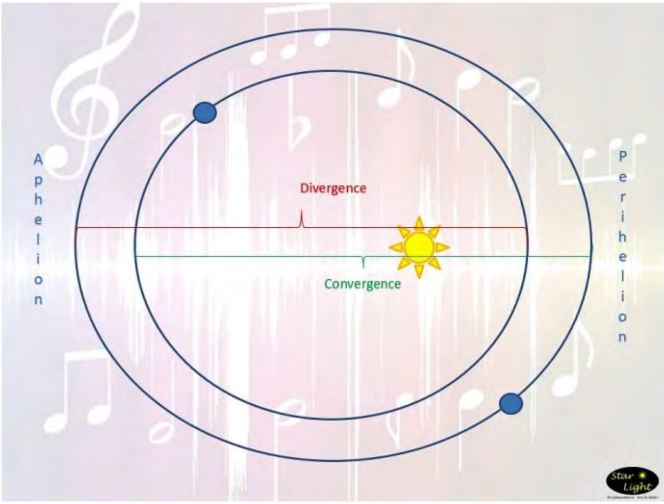

Fig. 5 *The convergent extreme motions, i.e., those that are in the apses closest to each other (perihelion of the superior planet and aphelion of the inferior); and those divergent, that is, those that are opposite to the apses (aphelion of the*

PLANETS	Harmonies of pairs of planets	
	Convergence	Divergence
Saturno – Giove	1/2 *Octava*	1/3 *Octava + fifth*
Giove – Marte	5/24 *2nd Octava + third minor*	1/8 *3rd Octava*
Marte – Terra	2/3 *Fifth*	5/12 *Octava + third minor*
Terra – Venere	5/8 *Third major*	3/5 *Third minor*
Venere – Mercurio	3/5 *Third minor*	1/4 *2nd Octava*

Fig. 6 *Comparison the ratio found between the amplitudes of the orbital arcs traveled by two adjacent planet in the most static moments with those of musical intervals.*

Fig. 7 *The Kepler's pentagram*

Kepler represented on a rope the mathematical ratios calculated for the intervals and showed that they were consonants both with respect to the whole string **(Fig.1)** and to each other. Kepler sought all the consonances of a monochord, even on a circle, the basic figure of the perfection of the universe, thanks to the division of the closed line by the inscription of regular polygons and with them built the harmonic relations between the planets; through the diameter → 2, the triangle → 3, the square → 4, the pentagon → 5, the hexagon → 6 and the octagon → 8 (**Fig. 2**). Comparing the arc subtended by one of the sides with the remaining arcs, he obtained exact octave ratios corresponding to the first harmonic consonances of octave, fifth, fourth and third major. The reference circle was for him the zodiac, against which the calculations of the conjunctions of the planets were made and, therefore, it was possible to highlight the correlation between the regular polygons inscribed in a circumference and the distances of the planets from the Sun.
But this path was not satisfactory, since the inscription and circumscription model of regular polygons could be carried out indefinitely, while there were only six known planets. Moreover, it was not consistent to insert flat figures between the solids represented by the spheres, in which the planets were thought to be embedded. At the center of this heliocentric model of a closed and harmonious universe, Kepler placed the Sun and surrounded it with the five spheres, on which the five known planets were inserted. The Earth was placed as a divider between the stable solids (cube, tetrahedron, dodecahedron), external to its orbit, and the unstable ones (octahedron, icosahedron), internal to it. In stable solids, the symmetrical axis of rotation passes through the center of a face; while in the unstable solids it passes through a corner; both types of symmetry are valid for the tetrahedron (**Fig. 3**). In this reorganization all the faces of each polyhedron appeared to be equidistant from the center and tangent to a single inscribed sphere and all angles were equidistant from the center and defined a sphere circumscribed to the figures. The ratio between the rays of the two spheres, which referred to each polyhedron, was well defined and characteristic: the tetrahedron corresponded to the larger ratio, perfectly at 1: 3; the cube and the octahedron corresponded to 1: √3; the dodecahedron and the icosahedron, 4: 5. This hypothesis gave a justification both to the number of the orbits of the planets and to their distance from the center of the planetary system, ie the Sun, to which Kepler had attributed the ability (virtus) to regulate the different speed of the planets according to the proximity or distance of their orbits from it.

But the calculations showed quite the opposite: the position of the regular solids between the orbits did not agree with the distances obtained from the observations made by Tycho Brahe, because these suggested not perfectly central distances of each planet towards the Sun: the real distances differed with errors up to 40%. Thus, he abandoned the painstakingly constructed model, but did not give up geometry. He then concentrated on the definition of the elliptical orbits traveled by the planets and, trying to show that the causes of eccentricities and periods of the orbits of the planets corresponded to harmonious proportions (or consonances), he arrived at the formulation of his Three Laws. Kepler noted that the velocity of the planets varied continuously from a maximum to a minimum and he hypothesized that each speed had a corresponding frequency, and the set of all frequencies generated a melody. Each planet, in tracing its orbit, generates its own characteristic melody; the more extended the frequency range, the greater the eccentricity of the ellipse. He calculated the amplitudes of the orbital arcs traveled by each planet in the most static moments, that is, those of aphelion and perihelion, and he compared the ratio found between them with those of musical intervals and found the correspondence (**Fig. 4**). This observation led him to shift his attention to the amplitudes of the orbital arcs traveled by two adjacent planets, to evaluate whether they also produced musical intervals. Using the values found in aphelion and perihelion, he calculated the convergent extreme motions, i.e., those that are in the apses closest to each other (perihelion of the superior planet and aphelion of the inferior); and those divergent, that is, those that are opposite to the apses (aphelion of the superior planet and perihelion of the inferior) (**Fig. 5**). From this he derived the relationship that linked the axes of the ellipse and the orbital periods and came to the formulation of the so-called "harmonic law", published in 1619 in Harmonices mundi, book 5 chapter 3:

"Res est certissima et exactissima, quod proportio quae est inter binorum quorumcumque Planetarum tempora periodica, sit praecise sesquialtera proportionis mediarum distantiarum".
(It is very certain that the proportion that binds the periodic times of each pair of planets is precisely the proportion sesquialtera of the average distances).

Each pair of adjacent planets, in the path of their orbit, generate a different melody in their divergence and convergence (**Fig. 6**).

Kepler was ready to write his pentagram (**Fig. 7**).

ACKNOWLEDGMENTS

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Programs for those with special needs

BIOGRAPHIES

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ABSTRACT

Simonetta Ercoli: "A Sky to touch"
The "Starlight, a Handy Planetarium" Association ran a workshop for schools called "Hunters of Constellations," in which some exhibits involved blind students. We chose to have the exhibit feature the main north circumpolar stars. The star positions were incised on a metal panel, on which the stars and the connecting lines could be identified by touch. Following this first activity, students worked with wooden blocks, each one having small nails for stars of a circumpolar constellation. Mentors guided the blind students to connect the stars with a tread, making a constellation figure. We gave two other workshops, one featuring lunar phases and the other about eclipses. For the lunar phases workshop we made six discs attached to a sheet of A3 Bristol card. Each disc was made of a different material so that participants could feel the difference between the light and dark sides of the Moon. We used NASA materials for the eclipse workshop.

David Hurd: "One Size Does Not Fit All: But at least I had something to try on!"
Those who are blind or visually impaired face unique challenges in science education in general and especially great challenges in astronomy education. NASA has collaborated with Edinboro University of Pennsylvania and the College of Charleston to create innovative tactile materials to assist the blind and visually impaired population. In this presentation, I will highlight past, present, and future projects to make space science more accessible to the visually impaired.

Shaaron Leverment: "Multisensory Top Tips!"
Explorer Dome has been operating for 20 years this year, and we always enjoy the work we do with special needs groups. Anything goes in special needs shows, and presenters have to stay fun and flexible! Above all we have adapted our shows to become more multisensory and hands-on at every opportunity. In this presentation Shaaron will describe some of the easy adaptations anyone can make to improve our offer to schools for children with special educational needs and disabilities.

Aase Roland Jacobsen: "Using Glow-in-the-dark gloves and sign language under the dome"
Glow-in-dark gloves are a useful tool in presenting sign language for deaf students under the dome. However, seeing just the gloves it is not enough. The students should also see the facial expressions associated with the sign language. At The Steno Museum Planetarium, we conduct astronomy programs in the dark beneath the dome using sign language in a special presentation with glow-in-dark gloves and a red spot. I will share with you how we present this type of program for deaf students or students learning sign language.

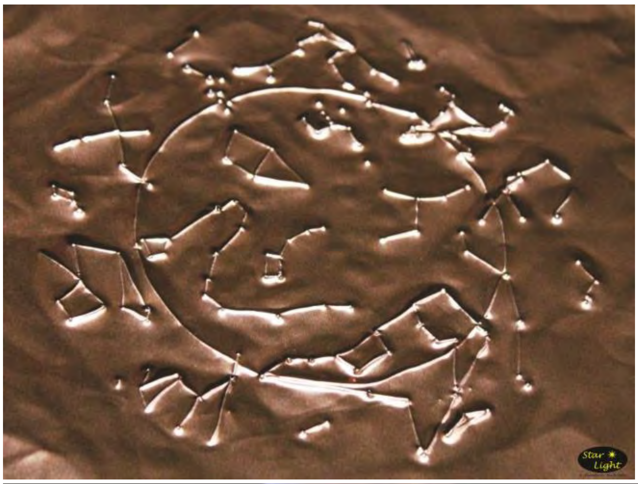
Michele Wistisen: "Engagement with Deaf Visitors In the Planetarium"
Over the years the planetarium community has struggled to provide an environment that meets the needs of the deaf. Funding and technology are issues that we confront in finding ways to serve the deaf in our audiences. Is will discuss technological advances used at some planetariums along with their pros and cons. These include Google glasses and an app with closed captioning

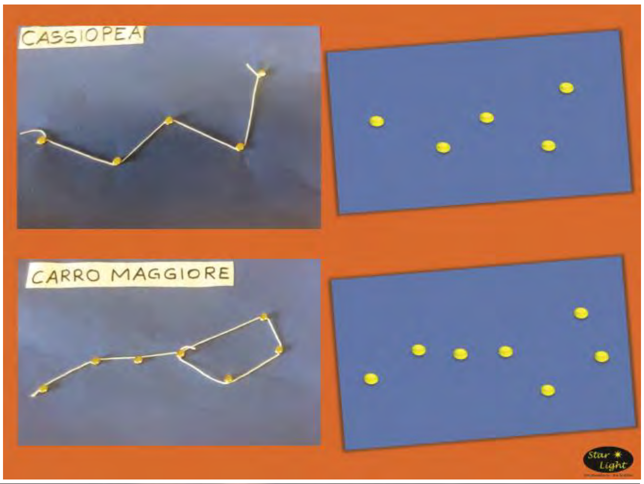
Tom Kerss: "The Royal Observatory and Planetarium Greenwich"
At the Royal Observatory Greenwich, we have developed a program for families of children with Autism Spectrum Disorder, retooling the Planetarium as a more accessible space. With careful planning, we have been able to provide a highly successful immersive learning experience for ASD audiences. I hope that in sharing our methods, I will encourage others to introduce their own programs that promote accessibility so that as many students as possible will experience their planetariums.

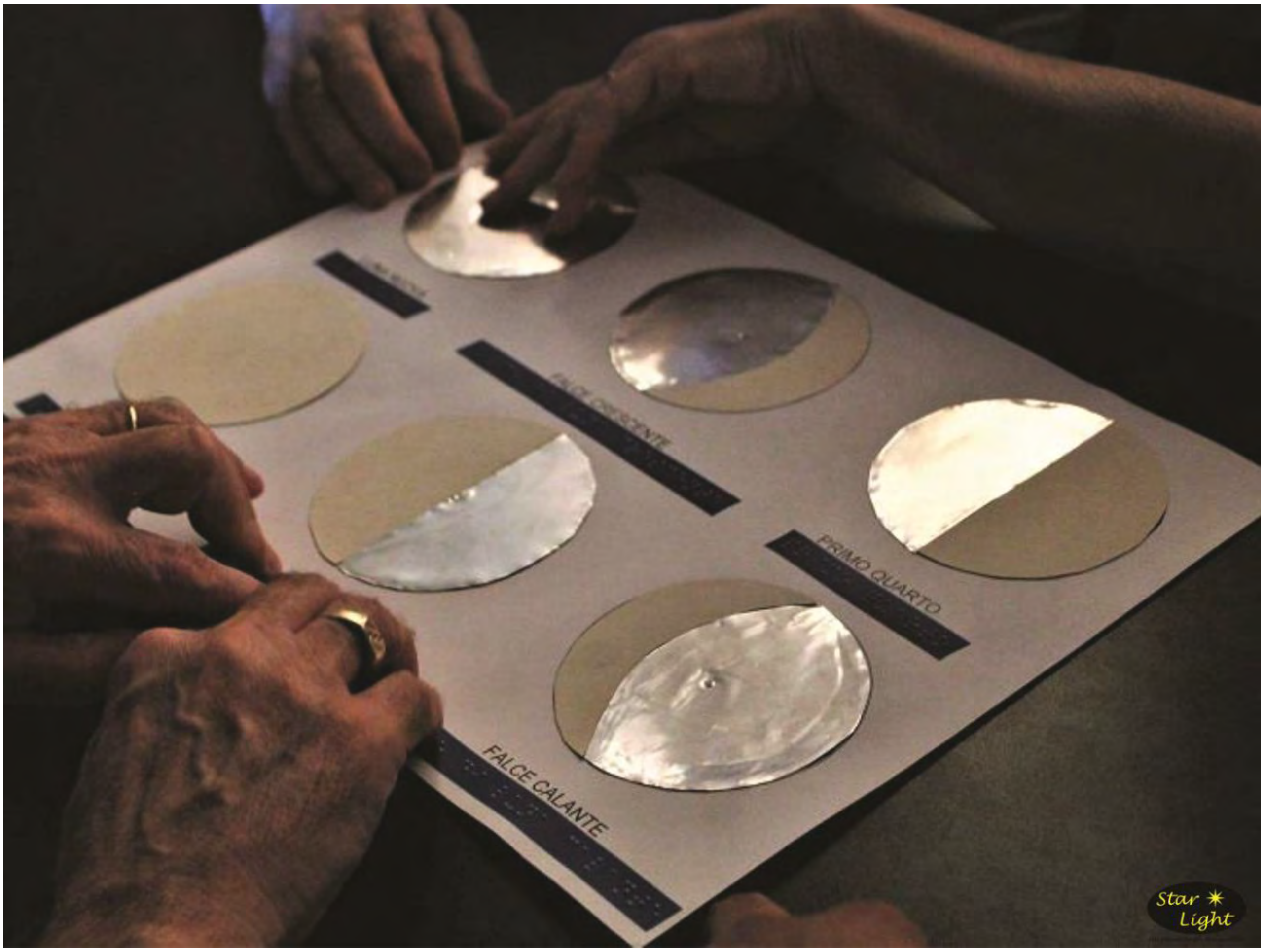
A SKY TO TOUCH

The “StarLight, a Handy Planetarium” Association ran a workshop for schools called “Hunters of Constellations”, for which some exhibits were made for work with blind students. As it was too difficult to explain all of the sky, we chose to make the exhibit just for the main circumpolar stars. They were incised on a metal panel, in which the stars and the connecting lines could be identified by touch.

After this first approach, the students worked on wooden blocks (one block for each of the main circumpolar constellations), in which stars were represented by small nails. Experts guided the students to connect the stars with a thread, so that they were able to make a figure of the constellation. Other two workshops are one for the phases of the Moon, with material produced by us, and the other for the eclipse, with a specific material from NASA. Our ‘homemade’ material consisted of six discs attached to an A3 sheet of Bristol card. Each disc was made of a different material so that participants could feel the difference between the light and dark sides of the moon.







ONE SIZE DOES NOT FIT ALL: BUT AT LEAST I HAD SOMETHING TO TRY ON!

We have all seen articles of clothes that claim to fit all sizes. Or at least they claim to fit a range of sizes. Unfortunately, those on the fringe who are too large or too small often end up wearing something that doesn't quite fit right. However true that may be, it is usually better to have something, rather than nothing at all. At our facilities we also deal with learners "on the fringe" that have special needs that we may or may not be adequately ready to address. Here too, it is better to have something in place (a plan or resources), rather than nothing at all. Your attempt at trying to meet those needs will help him/her experience your facility in the least restrictive manner.

You will note that I use the term "attempt" to try to meet the needs as it is also important to note that each individual with a special need is indeed "an individual" and comes with a unique set of challenges. One size does NOT fit all, but it is important to have some tools to use when they do arrive so that we can give them the least restrictive and most beneficial leaning experience possible. Although I work extensively with those who are blind or visually impaired in conjunction with NASA's Solar System Exploration Research Virtual Institute SSERVI (California, USA) and College of Charleston, (South Carolina, USA); we do not have all the answers. Some of those with whom we work are totally blind, some are low vision; some are tactile literate (can efficiently explore with the hands and translate into mental images) while others are not. Others have multiple disabilities along with visual impairments, such as hearing impairments, and/or physical or learning disabilities. The wide array of visitors that come to our facilities with special needs is staggering and our goal is not to meet every single need, but rather meet enough of the needs, by providing them with tools that reduce the restrictive nature of our programs.

So this paper is not so much to give you the "answers;" instead it is to highlight what we do and try to do well and what others do and what you can do to be prepared for those special needs visitors who will bring a special presence into your facility. All while arguing there is terrific value in having tools and/or resources in place, even if it doesn't quite "fit" the intended user.

Working in the planetarium presents a unique set of challenges for those with visual impairments as most of the planetarium medium is visual. In order to help visitors with visual impairments, Edinboro University of Pennsylvania (USA), SSERVI and College of Charleston have teamed up to design, develop and produce several tactile resources. *A Tactile Guide to the Solar System, Getting a Feel for Lunar Craters, Getting a Feel for Eclipses, Mars Science Laboratory*, and other single page tactiles dealing with astronomy concepts have been developed and distributed around the globe to help provide the resources (tools) for planetarians to use when visitors with visual impairments show up. This year we are pleased to provide IPS members with a new book completed June 2018, *Understanding Small Worlds in the Solar System: A Tactile View*. This is part of a set of tactile books in production. Each book is linked to the text through a QR code that takes the reader to the associated text and other resources in multiple formats. The link can also be found at https://sservi.nasa.gov/books. The following is a poster that we present at conferences to make others aware of the efforts being done by NASA to help make space science more accessible.

MULTISENSORY TOP TIPS FOR ENGAGING CHILDREN WITH SPECIAL EDUCATIONAL NEEDS!

Explorer Dome has been around for 20 years. Reaching out to about 50,000 children and adults every year, we have met nearly 1 million children inside our portable domes. Our standard Space planetarium show has been enjoyed by hundreds of thousands of children, but for groups of children with special educational needs we have to go further to make sure what we bring is as multisensory and immersive a science experience as possible.

Keen to hear from the audience with top tips, and share our own, Shaaron will discuss how we include sights, sounds, sensations and even smells in our shows. Our Space show has morphed into a Space and Rockets exploration, bringing hands-on pop rockets inside the dome (and ear defenders for those who need it!), a tactile moon globe, soft squeezable stars, Makaton signing, soft candles for worried children and time for all to enjoy!. All this adds to the educational experience for children with special educational needs and disabilities and, unsurprisingly supports all learners! Maintaining our shows hands-on and aware of the needs of each individual always brings excellent feedback as every show is unique!

Logistics have to change with shows. We always welcome wheelchairs, provide a summary of the show to teachers and carers before if they need it, allow children to experience the dome alone if they are not able to cope in a group situation and allow for the extra time that groups might need. Most importantly, we all need to have open, honest and non-judgmental staff training to ensure that all presenters can ask questions in an open and frank discussion and try out techniques, preventing arrival on the day in school being surprised or even fearful of interacting with children with moderate, profound and multiple learning difficulties or behavioral problems. Knowing how to deal with unexpected situations with confidence, care and understanding is a presenter super power, and utterly crucial to this most rewarding part of the work we do.

USING GLOW-IN-THE-DARK GLOVES AND SIGN LANGUAGE UNDER THE DOME

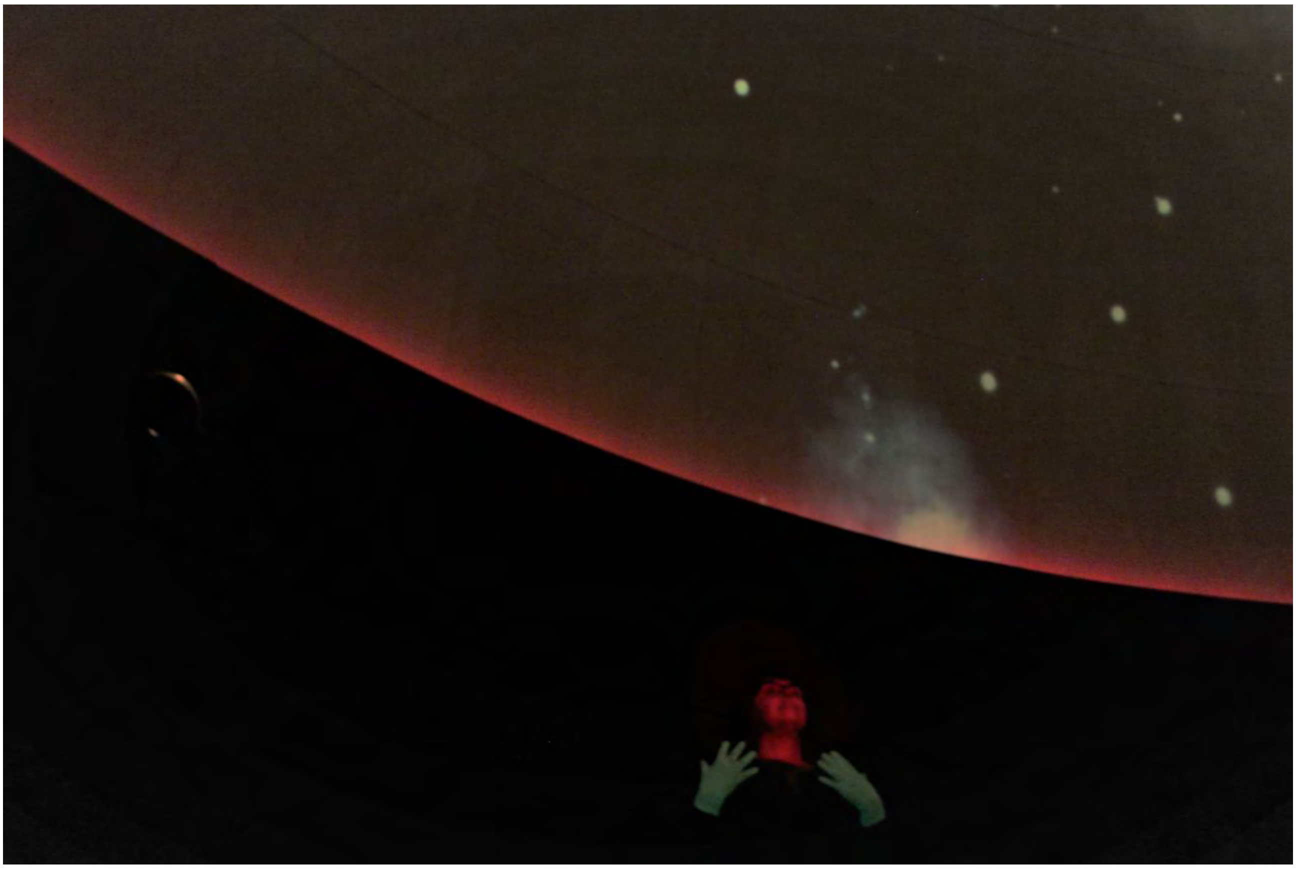
One of the challengers with sign language in the dome (and in the darkness), is that you should see the facial expressions, in addition with the sign language.

The technical set-up is rather easy. You will need glow-in-the-dark gloves, a red spot, a person that practice sign language, and a place in the front of the dome where students can see the sigh-language-person with the gloves and the facial expressions. You might find it most useful, if there is a second person that run the show, in addition to the person that do the sign language.

The Glow-in-dark gloves needs to be activated by light. Photo: Aase Roland Jacobsen

Normally, during a planetarium show, the presenter will speak while pointing out the stars on the dome or show contents on the dome. However, when using sign language, it is not possible for the students to look to up in the dome looking at stars or visuals at the same time as looking at the person doing the sign language. One good way to solve this is that you make a hand sign for “looking up”, so you will first speak and in the same time do sigh language. Then you stop speaking, make the “look up sigh” and then focus on the dome pointing out stars with the red laser pointer or show the visuals without speaking. Then go back for the speak/sigh language, then “look up sign” etc. etc.

That means if you have a normal presentation that last 50 minutes you need to cut down the contents, because it take more time to break the presentations into many parts or you need to expand the duration of the show.
Most of our presentations using sign language at The Steno Museums Planetarium have been done for groups that are attending the school where they learn sigh language. We hope that in the future, more focus on this kind of presentation and marketing of it, will spread the word, and we can reach out to more students with this special need.



Setup in the dome with Glow-in-dark-gloves, read light on the face and the "looking up" sigh. Photo: Kathrine Villadsen.

ENGAGEMENT WITH DEAF VISITORS IN THE PLANETARIUM

To date there have been many attempts to increase deaf visitors' engagement in the planetarium. During this session, Michele Wistisen, Casper Planetarium Supervisor, will focus on methods that are currently being used:

1. **Interpreter:** An ASL signer sits in a chair facing the hearing impaired. A red lamp is positioned next to the signer so their hands can be seen. IT is recommended that they wear white gloves so their hands will be more visible in the dark.
   Issues
   *Light can splash onto the dome when illuminating the signer
   *You may have to slow down the program to allow time for the signer
   *Student may miss information if the program is highly visual because they are more interested in watching what is being shown on the dome than the interpreter.
   *Deaf signing should also include the face of the signer
   *A signer may not know the signs for Astronomy terms

2. **Closed Captioning**
   Voice Recognition Closed caption: In a live presentation, the presenter communicates with the audience using a voice recognition system that translates his/her voice to a sign board.
   Issues
   *Voice recognition software may only be accurate in optimum situations where the speaker has devoted time to training the software to recognize his or her speech patterns, where audio quality and the acoustics of the recording environment are excellent, and where distracting background noises are minimal.
   Voice recognition for closed captioning: http://www.apptek.com/cc-appliance/
   Mock Closed Captioning: Use Power Point. The text is a light gray on a black background. The script of the show and directions for what the audience should watch for are included.

Issues

*A presentation may need to be slower to allow the audience to read and see what is on the dome.

*Very young children who are just learning to read will not benefit for closed captioning.

*The average reading comprehension score for deaf children is below the average comprehension score. Therefore closed captions may not improve learning.

*Where do you put the text so it is easily visible but not distracting?

Rear Window® Captioning System: Viewers pick up a reflective plastic panel mounted on a flexible stalk. The panel sits on the floor adjacent to the seat. A large LED display is mounted on a rear wall that displays caption characters in mirror image. Viewers move the panels into position so they can read the reflected captions and watch the presentation on the dome.

Issues

* It is sometimes necessary to sit in a certain area of the theater to obtain the best angle for reflecting the backward text emitted from the back of the theater on the panel while also being able to view the movie at the same time.

* Cost of the hardware (as of 2011, approximately US $4,500 per screen for a single installation). The cost of captioning a film is on the order of US $4,000 (about $40 per minute).

Closed Captioning through personal mobile device: Currently under development at the Adler Planetarium

3. **Head-mounted displays** : With a head-mounted display, deaf children can see sign language even when their head is turned away from the signer, allowing them to "hear" explanations and see scientific phenomena at the same time. Head-mounted displays (HMDs) are small computer screens attached to a glasses frame and worn next to the eye.

Issues

* Researchers studied the fit and balance of the display and also the size and position of the signer within the display. The signer shown in the display should be sized to match the relative real-world size relationship of the signer and the phenomena and the signer should be placed near the center of the student's field of view.

*Can deaf visitors understand new terminology shown? Even through students may have previous knowledge of deaf sign vocabulary, they may not be familiar with the signs combined to describe a specific astronomical object. (Example:sign for solid sphere and emission of light combine with motion to represent a Comet)

*The glasses from BYU are in development.
http://www.byuhci.com/wp-content/uploads/2017/09/View-of-Adoption-Of-ASL-Classifiers-As-Delivered-By-Head-Mounted-Displays-In-A-Planetarium-Show.pdf

*Hearing Connected eyewear developed by Cité des sciences et de l'industrie/R&D will be demonstrated in the RSA's dome by Christelle Barclay in session on the July 5, 2018 at 11 am.

THE ROYAL OBSERVATORY, GREENWICH

At the Royal Observatory Greenwich, we have developed a program for families of children with Autism Spectrum Disorder, retooling the Planetarium as a more accessible space. With careful planning, we have been able to provide a highly successful immersive learning experience for ASD audiences. I hope that in sharing our methods, I will encourage others to introduce their own programs that promote accessibility so that as many students as possible will experience their planetariums.

ACKNOWLEDGMENTS

Aase Roland Jacobsen would like to thank Kathrine Villadsen, Science Museums, Denmark, for taking the picture.

The Outer Universe and the Inner: - What is the connection?

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Email: urban.eriksson@fysik.lu.se

BIOGRAPHY

Dr. Urban Eriksson is an astronomy education researcher. His research focus is on what visualizations offers for learning astronomy at all levels, using a social semiotics framework. This involves disciplinary discernment and spatial thinking from different semiotic resources in relation to experiences offered e.g. by planetarium presentations.

ABSTRACT

Learning about space is by many considered exciting and challenging. A visit to a planetarium could provide experiences that leads to new learning about space and how the universe is structured. However, a planetarium presentation is visually vivid and the visitor will need to try to *read* the representations of astronomical objects as they are presented on the dome. If the goal of a visit is learning astronomy, there are things to consider as a presenter. In this paper, I present a framework for what to think about when tailoring the presentation and highlight the importance of disciplinary discernment and spatial thinking in the process of learning. A model is suggested that could help bridging the gap between the outer universe and the inner.

INTRODUCTION

Learning astronomy could be very exciting but also difficult for many people. The universe is so enormously large and distant. A visit to a planetarium opens up the universe for visitors but what do the visitors actually see, or *discern*, from the presentations they experience? What pictures of the universe do they build in their minds?

This paper concerns teaching and learning astronomy in planetaria and in particular what visitors discern from presentations. When presenting the universe on the dome for visitors, they will have to process the visual information discerned by them. This process is referred to as *disciplinary discernment* in the astronomy education research literature and has been proven to be limited for novice learners (Eriksson, Linder, Airey, & Redfors, 2014a). Moreover, the presentations, presented on a curved 2D surface, offers cues that could lead to an appreciation of 3D, even if the presentations are not done using 3D glasses. The most potential cue is parallax motion. However, research has shown that there are large variations in peoples spatial thinking competencies and discernment when it comes to *extrapolating three-dimensionality* in ones' mind from 2D presentations (Eriksson, Linder, Airey, & Redfors, 2014b).

In this paper, I discuss possibilities and limitations concerning disciplinary discernment and extrapolating three-dimensionality, using a social semiotic lens, where learning is connected to the competency to "read" astronomical representations presented in planetaria and elsewhere in astronomy contexts. I highlight the importance of purposefully bridging the real outer universe with the inner universe in people's minds through appropriate scaffolding using the Spiral of Teaching and Learning (Eriksson, 2014, 2017).

I. BACKGROUND

In the following I summarize the framework which this paper is based upon—social semiotics—and two important theoretical constructs—disciplinary discernment and extrapolating three-dimensionality. For a comprehensive review of the framework, I refer the reader to the work by the Uppsala University Physics Education Research group (eg. Airey & Linder, 2017).

I.1 Social semiotics and learning astronomy

There are many models that describes the process of learning. In this paper I use the framework called *social semiotic* (Airey & Linder, 2017) that draws on semiotic (Halliday, 1978; van Leeuwen, 2005), multimodality (Jewitt, Kress, & Mavers, 2009; G. Kress, 2010; G. Kress, Jewitt, C., Ogborn, J., & Tsatsarelis, C., 2001) and variation theory (Marton, 2015; Marton & Booth, 1997). It is a broad construct where all communication in a particular social group is viewed as being realized through the use of semiotic resources. In social semiotics the particular meaning to be constructed from these semiotic resources is negotiated within the group itself and has often developed over an extended period of time (Airey & Linder, 2017, p. 1). In astronomy such semiotic resources could be graphs, mathematics, diagrams, images, written and spoken language, gestures, animations, simulations, telescopes, CCD-cameras, planetarium, etc. Often many of these are referred to as *representations*. Learning astronomy can then be viewed as coming to interpret and use the meaning potential (disciplinary affordances) of disciplinary-specific semiotic resources (representations) that has been assigned by the astronomy discipline. This is in principle similar to learning a new language and it is here that we see the connection to semiotics; to learn astronomy the novice needs to learn how to "read and write" all the representations that the discipline uses to communicate meaning—a formidable challenge! This also suggests that to learn an astronomy concept a novice needs to learn all the different forms of representations and how they interplay, because one form of representation is rarely enough to convey all disciplinary meaning about a concept. In the literature this is referred to a *critical constellation of disciplinary semiotic resources* that is necessary for an appropriate experience of disciplinary knowledge (Airey & Linder, 2009, 2017). As such, in social semiotic, we ask what meaning a semiotic resource can convey and how that meaning is constructed by students, rather than asking what a particular semiotic resource is a representation of. For example, take an "image" of a nebula, see figure 1. This is a representation and NOT an actual image since it is constructed by astronomers using information gathered by a telescope, filters and a CCD-camera. It is then computer processed and constructed to highlight certain features and disciplinary relevant aspects (DRAs)(Fredlund, Airey, & Linder, 2015). Therefore, this representation holds particular meaning for the discipline and it thus becomes interesting to study how that meaning is constructed by novices. However, it is not immediately clear what meaning a representation hold, since it usually has a range of meaning potentials. In social semiotic, representations do not have a single fixed meaning, but rather a set of disciplinary-specific meaning potentials, or *disciplinary affordances* (Airey, Eriksson, Fredlund, & Linder, 2014), defined as "the agreed meaning making function that a semiotic resources fulfils for the disciplinary community" (Airey, 2015). It is then up to the novice to learn to discern these affordances, a process that is neither easy nor straight forward. Here, the presenter (teacher, lecturer, professor, etc.) of some material will inevitably need to unpack the disciplinary affordances for the audience (Fredlund, Linder, Airey, & Linder, 2014), or else these affordances may be completely invisible.

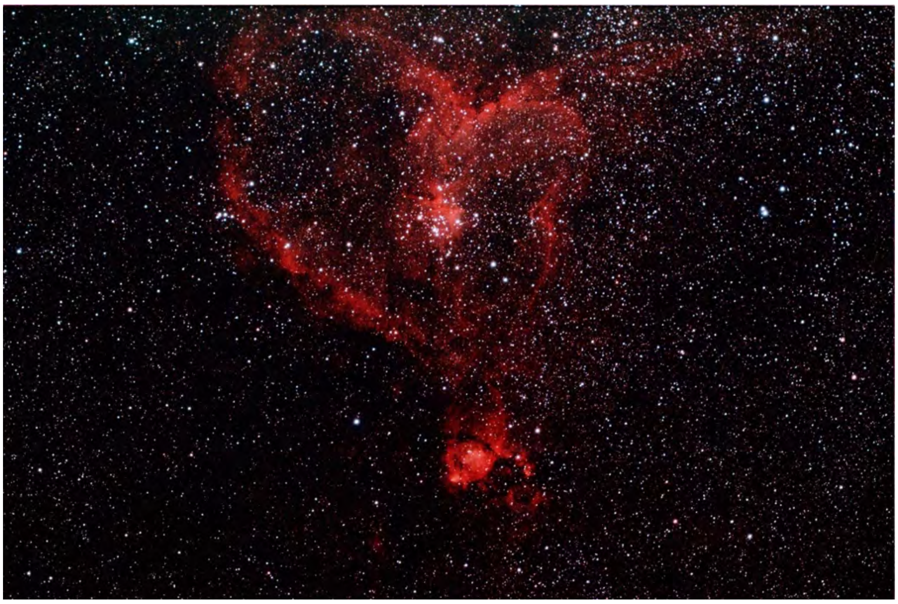

Figure 1 – The Heart nebula. This is NOT an image but a representation of the astronomical object constructed by the photographer. Image credits: Jonas Carlsson

I.2 Disciplinary discernment

When a novice looks at a representation of an astronomical object, (s)he tries to make sense of it. This process can be described by the following steps: first, one needs to *notice* things in the representation (Lindgren & Schwartz, 2009; Mason, 2002), second, one need to *reflect* on that noticing (Schön, 1983), and third, one *construct meaning* (Marton & Booth, 1997) from a *disciplinary perspective*. Elsewhere I refer to this as *disciplinary discernment* (Eriksson et al., 2014a, 2014b). This is different from ordinary discernment in that it needs be grounded in the discipline. Taking this as our point of departure, learning can be framed in terms of discerning the meaning potentials of the representations used by the discipline. However, the discerned disciplinary affordances of a representation are different for different persons and constitute a subset of the total disciplinary affordances, set by the discipline community, of that representation (cf. Podolefsky & Finkelstein, 2008). This can be described by the Anatomy of Disciplinary Discernment (ADD) hierarchy (Eriksson et al., 2014a), which describes the developmental characteristics of the ability to discern disciplinary affordances of representations. There is a clear connection to disciplinary knowledge; the more disciplinary knowledge one has, the more can one discern from a disciplinary-specific representation. I will come back to this below. Taking this approach, it is easy to see that different persons discern different things from a representation and the ADD hierarch describes the different levels on which one can discern. As such, disciplinary discernment becomes an educational issue to consider when presenting aspects of the Universe in e.g. planetaria. One of the most common "mistakes" done by presenters is that one think that the audience "sees" the same things as you, the expert, do, and starts to talk about objects and their properties on a level that is beyond what the audience can discern.

I.3 Extrapolating three-dimensionality

There is however a special part of disciplinary discernment that deserves more attention. It is strongly connected to fact that the universe is multidimensional (3D + time) and for someone to come to appreciate and understand the universe, one needs to learn to "see" it as multidimensional. This take a lot of spatial thinking and it is exactly here that we face a major challenge (eg. Plummer, 2014). Form our daily (or nocturnal) experiences of watching the night sky, we can only see as a curved 2D surface; we cannot see depth. Astronomical objects, even the closest one, the Moon, is so far away that we cannot determine its distance and hence not its actual size from looking at it. This is of course due to the astronomical distances in the universe and that we are stuck here on Earth and cannot see astronomical objects from different directions. Even though we travel around the Sun, and by that have slightly different viewpoints, the astronomical objects are so distant that we cannot experience them as different from these different viewpoints. Indeed, we have great problems seeing them at all, since they are so distant!
Learning astronomy then become a real challenge to novice; you cannot see most of the universe and the little you can see is so far away the you don't get a feeling for distances. In principle one is left with a flat 2D view of the universe.
How can we then address this when learning astronomy? Here we use telescopes for gathering information. From this information astronomers create representations and *it is from those representations that novice learns about the universe*! Those representations hold disciplinary affordances and these needs to be discerned by the novice. A particularly challenging aspect is the three-dimensional nature of astronomical objects and their spatial distribution, an aspect very important for building deeper understanding about the universe. Historically, most representations are either 1D (mathematics and text) or 2D (graphs, images, tables, etc.) and it from these that the novice build understanding of the 3D universe, or even 4D if taking time into account. I refer to this process as *extrapolating three-dimensionality* from 1D and 2D input (Eriksson et al., 2014b).
In a previous study it was found that the competency to extrapolate three-dimensionality vary a lot and could be described by a multidimensionality discernment hierarchy (Eriksson et al., 2014b). The perhaps most important findings from that study was that if one use simulations/animation to represent a 3D object on a flat screen and virtually move around it, viewing it from different directions using parallax motion, many participants reported that they came to understand the structure much better. It is here that presentations in planetarium could make a huge difference for peoples understanding of the universe (C Aaron Price, Hee-Sun, Plummer, SubbaRao, & Wyatt, 2015; C.Aaron Price, Lee, & Malatesta, 2014; C Aaron Price, Lee, Subbarao, Kasal, & Aguilera, 2015). In planetaria, we have the tools to present astronomical objects (at least some) in 3D and at the same time their relative position in 3D space. The planets and moons in the solar system, and some exoplanet systems, are nowadays unproblematic to present and thanks to the work of astronomers (eg. Steffen, Koning, Wenger, Morisset, & Magnor, 2007) and astronomy visualizers around the world some nebulae can now be presented using realistic 3D virtual models based on observational data. In a not so distant future, many more astronomical objects will be modelled based on observational data and being possible to present in planetaria around the world, enhancing the possibility from visitors to learn about the universe.

II. PLANETARIA VISITS AND LEARNING ASTRONOMY

From the comprehensive review of educational research done in planetarium by Slater and Tatge (2017) it is clear that not much research have been done over the years concerning spatial thinking and extrapolating three-dimensionality. However, there have been a few important research projects that has addressed this aspect in relation to learning astronomy (eg. Eriksson et al., 2014b; Plummer, 2014; C Aaron Price, Hee-Sun, et al., 2015; C.Aaron Price et al., 2014; C Aaron Price, Lee, et al., 2015), often (only) in relation to seasons and the phases of the Moon. It is found that people do benefit from being taught astronomy by specifically addressing and taking into account the 3D aspect. From the literature it can be concluded that what in all cases the base line is the use of representations and how these are presented. Moving from static 2D representations (as often presented in text books), see figure 2, to dynamic 3D representations, which can be viewed from different direction using motion parallax, makes a huge difference when it comes to learning about these concepts. Here, planetarium presentations provide the necessary vehicle which, together with the presenter, potentially could make a big difference for learning astronomy.
These findings contribute to the idea that when optimizing learning astronomy one need to specifically address the three-dimensionality of space.

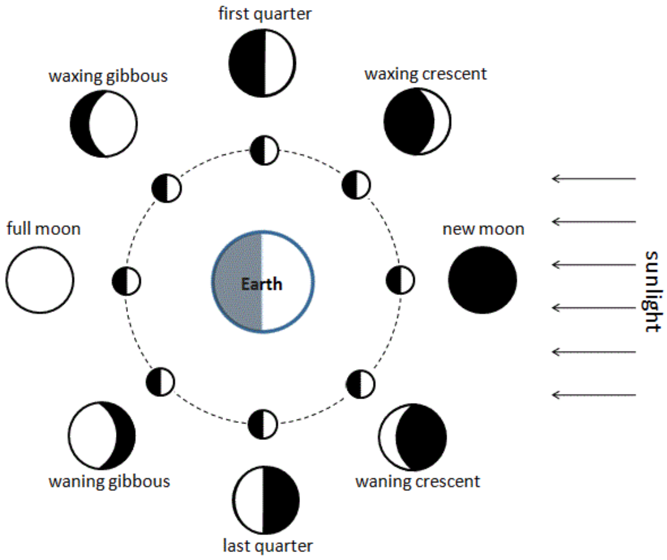

Figure 2 – A 2D representation of the phases of the Moon. Such representation is common in many text books, while at the same time being known to enhance misconceptions concerning many astronomy concepts related to the Earth—Moon system. It is very hard to extrapolate a correct scientific three-dimensional image in one's mind from such representation. Image credits: Wikipedia

III. THE SPIRAL OF TEACHING AND LEARNING

From the above it is clear that planetarium presentations make a positive impact on learning astronomy. How, then, do one create the optimal situation for learning an astronomical concept, say nebulae, in a planetarium setting? Of course, I cannot fully answer that question but I like to propose a theoretical model where I take into account certain aspects important for learning. However, to learn about the universe the first thing one need is *experiences* and some disciplinary knowledge. To experience one need to open one's mind and "look up". This is the foundation for all learning and for learning astronomy in particular. Therefore, any planetarium presentation must be created to provide the intended experiences by the audience, and not more or adding extraneous load, hence reducing the risk of cognitive overload (Mayer, 2009; Mayer & Moreno, 2003). When visiting a planetarium show/presentation there is always the "wow"-effect to consider. Most people will be amazed by what they see and this could be a good thing. But, how do one know what is important and not important in what is visually presented for you?

Building on the framework discussed above, there are at least three concepts important to consider for a presenter/teacher: disciplinary knowledge, extrapolating three-dimensionality and, disciplinary discernment (Eriksson, 2014, 2017). These form the foundation upon which teaching and learning astronomy could be modelled—the Spiral of Teaching and Learning. This theoretical model describes a progression where one must consider not only the audience disciplinary knowledge but also what representations one use and what disciplinary affordances they hold, while at the same time addressing spatial thinking. The model, see figure 3, builds on Bruner's (1960) spiral curriculum idea, where one should start at a simplified level first and then recursively revisit it with more details later on. Here, I suggest that it is equally important to address disciplinary discernment and spatial thinking as disciplinary knowledge. The presenter needs first consider what disciplinary relevant aspects (Fredlund et al., 2015) to address and the how to scaffold the audience to discern the intended meanings (affordances) of a chosen representation of an astronomical object/concept, starting with simple things first, and then revisit with more details after that. Again, consider the importance of addressing spatial thinking.

Optimal could be to help the audience discern structures of, say, a nebula, then rotate the nebula model to see it from different directions, discuss what these structures could mean and how they function, then come back to the structures again in more detail, move around to see it from other directions and discuss more disciplinary knowledge related to that, and so on. Here, it is important to listen to the audience to learn if they follow the line of thinking towards a deeper understanding of the concept. Therefore, the communication between people in the audience and the presenter is very important to create the best possible learning situation. This communication will consist of the presentation ("the show"), verbal ("talk") and gestures ("waving hands) and it is important to encourage this as a presenter. In social semiotics learning is a social process and (metaphorically) the *reading* (disciplinary discernment) and *writing* (talking, waving hands) of representations is at the heart of learning. So, as a presenter, and using the spiral approach, learning possibilities increase and the audience is likely to leave the planetarium theater enlightened and more knowledgeable than before.

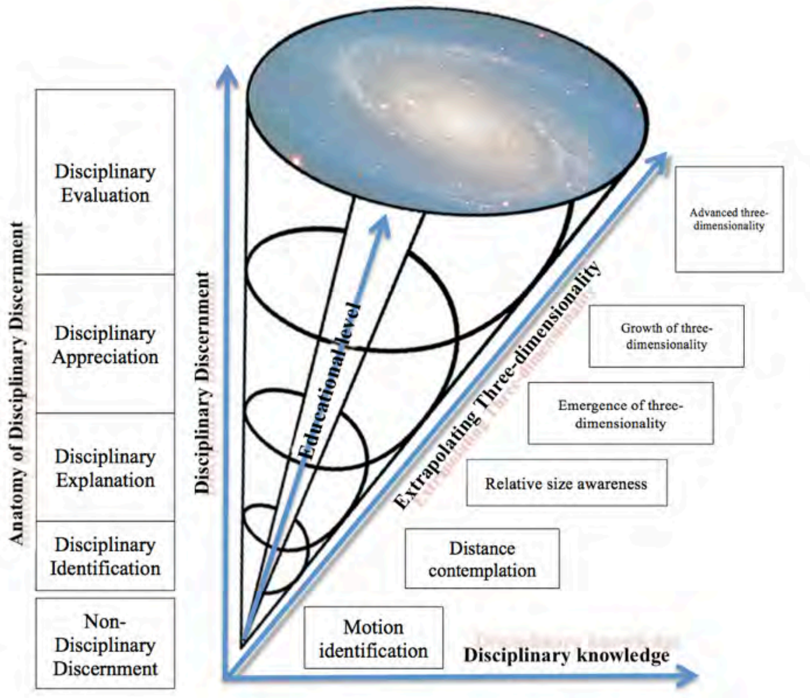

Figure 3 – The Spiral of Teaching and Learning.
This model describes a theoretical approach to teaching and learning astronomy, taking into account disciplinary knowledge, disciplinary discernment and extrapolating three-dimensionality (Eriksson, 2014).

IV. SUMMARY

It is always difficult to know what visitors to a planetarium show learns from the presentation. What we do know is that they discern very little and different things from what we expect. Therefore, it is important to consider what a presenter want the audience to learn from the presentation. In this paper I have highlighted the importance of two concepts vital for the process of learning astronomy: disciplinary discernment and extrapolating three-dimensionality. If the goal of a presentation is to teach about astronomy, these concepts needs to be taken into account when planning the presentation and I suggest doing so by following the Spiral of Teaching and Learning. One must remember that learning astronomy from the representations used in a presentation/show is like learning a language; one needs to learn to *read* (and *write*) these representations. This is challenging since they hold many disciplinary affordances that could be invisible to the audience. Therefore, the presenter will need to take the role of a teacher and scaffold the audience to discern the intended meanings of the representations of astronomical objects, also taking spatial thinking into account. Then people starts to notice things and differences between things and build a 3(or even 4)D understanding of the Universe in one's mind, hence bridging the gap between the outer and inner universe.

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Antoine Darquier, his discovery of Lyra Ring nebula and astronomy in the city of Toulouse

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If the expression " planetary nebula " is of William Herschel, it is not foreign to the discovery of Lyra Ring nebula at Toulouse in February, 1779 by Antoine Darquier de Pellepoix. Indeed, this one compared it by the shape and the thickness with the planet Jupiter. Come back on the conditions of his discovery and biographic approach of a French observer of the Age of the Enlightenment whose tercentenary of the birth we celebrate, in this year of the IPS-2018 in Toulouse.

Life and work of Antoine Darquier (1718-1802)
The awakening of a vocation
Antoine Darquier de Pellepoix was born on November 23rd, 1718 in Toulouse and died January 18th, 1802 to Beaumont-de-Lézat, at the age of 83. After his studies to the College of the Jesuits in Paris, he returns in Toulouse because of the fragile health of his father. In the foreword of the first volume of his astronomical Observations, he indicates dedicating itself to the astronomy having attended sessions of the *Société des Sciences de Toulouse*. Raise of the class of geometry in 1739, his first communication goes back up on March 26th, 1744 and door on the movement of planets. According to these diverse elements, we can consider that it is near 1745, thus towards the age of 27 years, that takes form its interest in celestial bodies, passion which it exercises till the end of his life.

Darquier and Garipuy: a work which ends in the emergence of Toulouse Observatory
How to present Darquier without evoking François Garipuy (1711-1782), of seven years his older ? It is this main astronomer of the Society of the Sciences that arouses its interest. On its initiative, the Company establishes an observatory on the Tower of the Rampart St-Etienne in 1734. The astronomers observe there together the big phenomena. This threatening Tower ruins, both observers, bothered by its estrangement, decide by 1750 to establish in their properties their own observatories. It is shortly after the call of Delisle to lead observations corresponding to those of Lacaille in the Cape of Good Hope in 1751 and 1752. They are realized in Toulouse by Garipuy and Darquier with a quarter circle of two and a half feet of Langlois acquired by the Academy (today kept to the Museum of the Paris Observatory), and a glasses of Darquier of seven feet stocked with a micrometer, placed on a wooden sector of five feet of beam. They end in a parallaxe of the Sun of 8,5 *"giving evidence of the quality of their observations ».*
Next years, Darquier, provincial Conductor of the Clergy and the impositions of the Auch’s district, fits out his observatory. Garipuy, Civil engineer in Languedoc, ceases its activity about twenty years. By 1770, he replaces his observatory, by a new one at the top of his house, magnificent, more spacious, in a room of 20 feet of internal diameter (with four terraces to move forward instruments to four cardinal points) and a closed dome representing the boreal constellations. We can see a representation on an engraving accompanying a study of Bigourdan in 1886, with the mention of the Lyra nebula ; joke of the biographer, because it is indicated that this engraving is inspired by a watercolor drawing of 1774, time preceding the discovery of the nebula. In fact, the original drawing, preserved to the Archives of Toulouse, dates 1826. It contains a signature of Carney, president of the Academy but is most probably Julien Rivet's work, an architect alumnus of Darquier, who oversaw then the restoration of the observatory.
When Garipuy built its observatory at the top of its house, Riquet de Bonrepos, grandson of the builder of the Canal du Midi, establishes his, developing with Vidal that he recruits as astronomer of the meridian observations of Mercury.

This type of observations is also gone deeper into by Darquier and arouses the general interest of the astronomers. Lalande write in his *Astronomy* (t. IV, p. 587) published in 1792: *"Toulouse. Mr Darquier published a big collection of observations in 1777. Mr Garipuy built a beautiful observatory in his house in 1773. M. de Bonrepos did one in his earth near Toulouse. It is all the provincial towns that where the astronomy is the most cultivated".*
The astronomical brilliance of the pink city is sealed by the deliberation of the States of Languedoc to acquire of Garipuy's observatory shortly after its death in 1782 to became the Observatory of the Province.
One thing leading to another, the provincial observatory, entrusted to the Academy, becomes in the Revolution the National Observatory of Toulouse endowed with a paid staff. After a municipal status in 1808, it takes a new impetus from 1840, with the rise of domes on the hill of Jolimont. Garipuy is thus twice at the origin of the observatories of the Toulousian Academy, in the Tower of ramparts, then at the top of its house. But the latter would not probably have been saved in 1782 without the share and the scientific aura of Darquier, author of his academic praise.

The written work of Darquier: works of observations, popularization and translations
The main contribution printed of Darquier is the complete edition of its observations on five decades (1748-1798), extremely rare fact. His astronomical Observations appear in two volumes: the first one printed in Avignon in 1777, for the period (1748-1777) and the second printed in Paris in 1782 for the period (1777-1780). Then, three consequences are inserted at the end by volumes II, III, and IV of the Reports of the Academy of Toulouse covering the period (1781-1791). Finally, after the dissolution of Academies in the Revolution, Lalande inserts the period (1791-1798) into its *French celestial History*.
In the register of the popularization, Darquier joins as a precursor through its two works, *Uranography* and *Letters on the practical astronomy*, which would find both domains of the popular astronomy and amateur's astronomy today, but in the sense of its period.
Uranography or pondering over the sky within the reach of everybody, was edited in Paris in 1771, republished in 1780, then in 1786 at the end of its *Letters on the practical astronomy*, edited in Paris by Didot. Darquier practice four languages : English, Italian, Spanish and German, language acquired to maintain a long correspondence with Jean Bernoulli. He translates in particular the *Cosmological Letters* of the mulhousien Lambert.

Darquier, an astronomer to rediscover…
Darquier give us a very singular contrast regarding investment between what we believe to be useful for the science and what the situation is for the test of time. Because finally, here is an amateur who observes accurately the sky during more than half a century, who does not arrange his efforts to publish (on his personal fortune, rare fact to be underlined) its thousand meridian observations of the Moon, the planets and the stars, reduced, commented and classified chronologically, as well as all the announced or impromptu phenomena, moon and Sun eclipses, aurora borealis ... A working sum of observation, calculation and considerable edition, today reduced to the state of archives in some libraries. Thousands of pages compared to which seem very derisory some lines granted to this nebula of the Lyre, considered by his discoverer as a simple curiosity, while it turns out the vector immortalizing its work...
It is the Canon Louyat who really brings out Darquier of the shade in 1960. He suggests a commemorative tablet on his hotel. It is however necessary to wait for 1984 so that it succeeds, during a ceremony in the presence of the Mayor of Toulouse, Dominique Baudis. Organized by Louyat, the remembrance is accompanied in particular with communications by Jean-Paul Zahn, Director of the *Pic-du-Midi Observatory* and Jean-Pierre Brunet, President of the *Society of popular astronomy of Toulouse* and author of a first project *Toulouse Planetarium* in the 1980's years, who realized with Robert Nadal the inventory of its works (published in the magazine *Pulsar* of May-June, 1984). Meanwhile, Roger Jaquel, specialist of the works of the mulhousien Lambert, presents a communication on his translation of Lambert's cosmological Letters to the Congress of the Learned societies held in Toulouse in 1971. About twenty years later, during the same Congress held in Avignon in 1990, Simone Dumont redraws his admission to the Institute in 1796 together with three other Southern astronomers in the honor : Flaugergues from Viviers (Ardèche), de Ratte in Montpellier and Duc-Lachapelle in Montauban, completed in 1802 by that of the astronomer Vidal of

Mirepoix, director of the Observatory of Toulouse, pioneer with Bonrepos of the meridian observations of Mercury.

Today, a certain curiosity is perceptible to the author of the discovery of the nebula of the Lyre during colloquiums or through forums on the Internet. Both for its activity observationnelle and its open-mindedness for new ideas and for its literary and human qualities, Darquier deserves to be more known of the astronomical community. It is a happy initiative of International Planetarium Society to have chosen to organize its international conference in Toulouse in 2018 to commemorate the tercentenary of the birth of this informed amateur of the Age of the Enlightenment. A century coinciding with the big period of the astronomy of position, which the not slightest of the charms was that people of sciences which were designated philosophers, with a wider acceptance than that of today (the term scientists still not existing) were also mens of letters and culture.

The discovery of Lyra Ring nebula

The Ring nebula of Lyra (M57 in the catalog Messier and NGC 6720 in New General Catalogue) is one of the objects of the deep sky the most appreciated by the amateur astronomers. Situated not far from Vega, one of the three stars of the beautiful summer triangle, it is easily locatable by the amateur astronomers in a third of the line of the quadrangle of the Lyre joining both stars of the third magnitude, Sheliak and Sulafat of this constellation. Its discovery by Darquier is the second of the kind. With Dumbbell (M 27) in the Small Fox, discovered by Messier in 1764, Small Barbell (M 76) in Perseus and the Owl (M 97) in the Great Bear, it is one of the four planetary nebula of the catalog Messier and it is often considered as the prototype of this type of nebula. Nowadays, about 2.000 are listed in the Milky Way, where we esteem their number around 50.000.

In spite of its naming, M 57 has nothing « planetary ». But in the eighteenth century, the astrophysics, the red giants and the white dwarfs were not still on the agenda, and the shape of these nebula gave them a family resemblance with planets resolved with visible diameters in the astronomical instruments. Thus it is quite naturally that Herschel established this naming in 1784. In fact, this discovery was made in a fortuitous way by Antoine Darquier in his exploration of the constellations crossed by the comet of 1779. He pointed immediately his researcher of comets and his glasses of Dollond in the concerned region and followed the evolution of this comet until March 24th. To establish the walking of the comet, he establishes in the second about fifteen February a catalog of 270 stars of the constellations of Berenice, the Crown, Hercule and the Lyre. In this context he tells the discovery of the nebula, some lines in the second volume of his *astronomical Observations* :

" I met some nebulas in my path, most of which are unknown; but the one in which I stopped with most complacency is a nebula situated between two beautiful stars of the third size of the Lyra ; it looks like no other one : it is big as Jupiter, perfectly round and well determined, mat as the dark part of the Moon in sizygies ; it seems that its center is a little less mat than the reflection of its surface... There is good reason to wonder that no astronomer spoke about it : it is true that is needed a rather strong glasses to perceive it. Would it be a new production of nature ? Or would it have the same date as the stars which surround it ? That is why we keep silent, not to deliver us to still imaginary guesses ".

Darquier used a glasses of Dollond of 3 inches and stand-off half (92 mm) and 42 inches of focal (1,10 m), rather powerful to suspect the center of the nebula of different aspect. It liked to say that his instrument *" had the same strength as that of Messier ".*

It should be noted that in a publication printed in 1782, the *Mémoires de l'Académie des Sciences*, 1779, we can read that Messier observed this nebula on January 31st, 1779, that is about ten days before Darquier does learn the existence of this comet, on February 9th, following her from the same evening till the end of April, what motivates him to study the crossed constellations. Thus it would be attractive to assert that Messier is the first discoverer of this nebula …

Yet, not only the columns of the astronomy mention the name of Darquier for 238 years, but there was no contesting at that time because Messier himself, in the edition of its catalog of 1781, associates the name of Darquier with the discovery of this nebula. And we know nevertheless the propensity which had Messier to claim its discoveries, whether it is comets or nebulas …

Besides, it is advisable to take into account all the elements of the context of a discovery by respecting the criteria of allocation of the astronomical discoveries. That they are amateur or professional astronomers, that they work in the XVIIIth or in the XXIth century, these criteria are the same for all the observers. And they are well known : it is the first one who communicates who is recognized as discoverer. We understand the race in which are engaged all the observers to be the first ones to warn the astronomical community to be recognized as discoverers. Everything is affair of chronology, not in the observation itself, but in the distribution of this observation.

The discovery of this nebula of the Lyre is not the fruit of the fate. It is due to the meticulous examination of the zone browsed by this comet of 1779 which Messier observed on January 19th, independently of Bode who had discovered it from January 6th. He immediately sent a note on the comet, published in the *Gazette de France* on January 26th. Darquier lay in Toulouse and the mail coach putting in the period about ten days to bring the information to this provincial town, he observed this comet from the night from 9 till 10 February. Yet, if Messier observed this nebula on January 31st as he asserts it in his text printed on one year later, I took care of verifying that we have no handwritten document giving evidence that he informed the scientific community immediately after his discovery : no dated letter, no article in newspapers, no register of observation with dates kept, even no manuscript in the Archives of the pouches of sessions of the *Académie des Sciences*. Nothing surprising in it, Messier was at first a hunter of comets, and he had undertaken his catalog of low objects only to avoid confusing these nebula with the new comets. These low objects (our current stellar or spherical galaxies, heap, diffuse and planetary nebulas, were then indicated under the general word of "nebulas" and were not on the agenda yet. It is moreover one of the main paradoxes of the observational science in the XVIIIth century : the name of Messier went down in history through its catalog of objects rather than by his about forty observed comets, of which near half bare or co-bare independently of other observers …

In the passage, if we examine the supplied descriptions, Messier is very light in its description of this Lyra Ring nebula that he claims to have observed January 31st, 1779. What includes because the Full moon, what arose the next day in February 1st, returned then the night-sky particularly little convenient to the observation - and even more, in the discovery - of an object as M57...

Darquier, without indicating the date of its observation, is more precise, comparing this nebula with Jupiter by the shape and the size, opening the way to the expression " planetary nebula " widely diffused by Herschel following his journey in England at the famous manufacturer of telescopes, discoverer of Uranus.

The manuscript of the " Memory on the comet of 1779 " of Messier not being preserved in the Archives of the Academy of Science, the only source concerning him whom we have is thus its text printed in the *Mémoires de l'Académie des Sciences* 1779, including its observations of this nebula in January and in September, 1779, followed by the observations of Darquier of the constellations browsed by the comet, made of February at the end of April, then taken back in July, 1779. In view of the former and current criteria of the astronomical discoveries, the difference is clear.

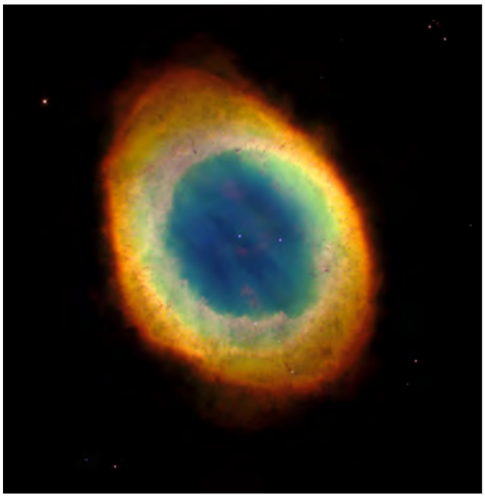
Even if we can suppose honest Messier in its assertions and admit that he observed this nebula M57 on January 31st, this source was printed in 1782, took out press with three years of gap. Whereas Darquier communicated well the first one its observations to the astronomical community from the summer, 1779 through the mention of this nebula sent to Messier. The conclusion is without appeal: by virtue of the fact that the discoverer of a new celestial body is the first one who communicates, the discoverer of the nebula of the Lyre is good Darquier.

It is doubtless unfair for Messier, but he would go away so nowadays for any talented astronomer who would discover a new object. If he does not immediately make known his observation and that another observer, although observing later, communicates more quickly, he cannot make validate his discovery …

The astronomy in Toulouse

Drawings on the walls of the Basilica Saint Sernin give evidence of an education of the astronomy in the thirteenth century with a geocentric representation, before the heliocentric revolution of Copernic. In the XVIIth century, father Minime Emmanuel Maignan (1601-1676) develop astronomical observations and gnomonical realisations. In 1648, he publishes his *Perspectiva Horaria*, voluminous treaty of gnomonics and optics. The Jesuit Michel Mourgues (1642-1713) observes the big comet of 1680. Guillaume Bonjour (1669-1714) imagine a project of calendar approved by Cassini and produce observations in China. Besides his observations, father Emmanuel de Viviers (1666-1738) designs an *astronomical, geographical and lunar Dial* for Toulouse.

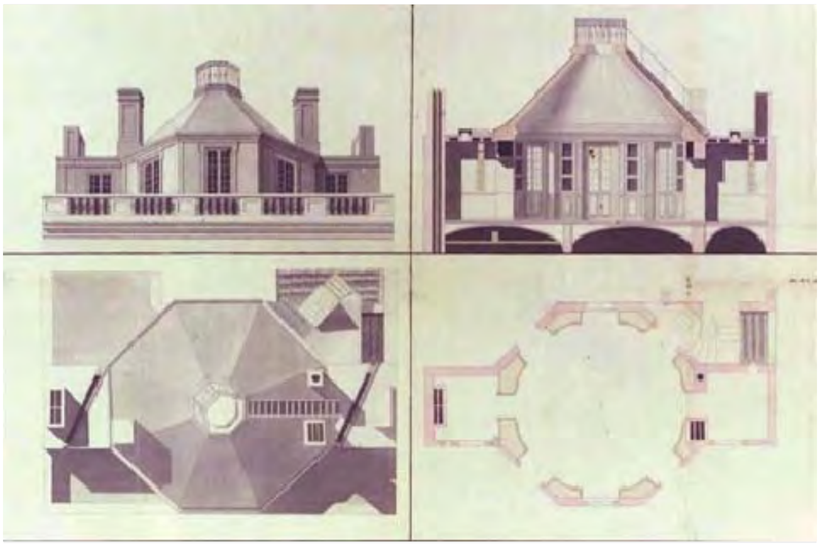
If Darquier and Garipuy dominates the middle of the XVIIIth century, Riquet de Bonrepos and especially Jacques Vidal (1742-1819) have developped their meridian observations of Mercury. In the XIXth century, Frédéric Petit (1810-1865) insures the transfer of the Observatory from the Garipuy's house Jolimont, developing this observatory that he makes equip big instruments of which the Foucault's telescope of 83 cm he orders, installed by his successor Féllix Tisserand (1845-1896) in 1875. Besides the foundation of the *Annales de l'Observatoire de Toulouse* en 1863, like popular astronomy class of Arago, he give a weekly public lessons, edited under the title *" Traité d'astronomie pour les gens du monde "*. Director in 1878, Benjamin Baillaud (1848-1934) completes the equipment (33 cm glasses in 1889, meridian circle), develops the photographic project of the Carte du Ciel and makes build the big dome of the Pic-du-Midi Observatory, which gradually takes over in the XXth century by the quality of its sky in 2877 m from height …



Ring Nebula (HST)

Antoine Darquier

François Garipuy



Watercolor of Garipuy’s observatory built in 1774 (1826)

Toulouse observatory (Jolimont)

Using the layers of presence as a framework for artistic practice in fulldome space.

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BIOGRAPHIES

Michaela French is an artist, designer and researcher working with light and immersive media. Her practice explores the interaction between light and body through innovative installations in fulldome, live performance, museums and gallery exhibitions. Michaela is a PhD candidate and tutor in Information Experience Design at the Royal College of Art, where she leads the Fulldome Research Group.

ABSTRACT

This paper adopts an ecological approach to presence theory derived from J.J. Gibson's ecological psychology to consider the ways in which the layers of presence can be used as a framework for creating artistic content for fulldome spaces. By considering presence as a process of ecological exchange and a natural embodied response to environmental stimuli, this paper moves beyond mainstream definitions of presence. Drawing on examples of recent fulldome films produced by the RCA Fulldome Research Group, this paper offers examples of how the concepts of proto, core and extended presence can be employed to create rich, evocative and engaging immersive experiences in fulldome space.

INTRODUCTION

Presence is central to the fulldome experience, it affords a suspension of disbelief and enables the viewer an expanded worldview. When imbued with presence, fulldome transcends the technical structures of the dome theatre and offers a rich perceptual experience which engages the body as the primary frame of reference and has the capacity to move and inspire an audience through evocative multi-sensory communication.

Presence has been described as 'a holy grail for immersive experience designers' (McConville, 2016) but this elusive, multifaceted concept defies a singular definition and its meaning and interpretation varies widely across disciplines. In this paper, I offer a definition of presence which derives from J.J. Gibson's ecological psychology. Moving beyond mainstream approaches to presence theory, this ecological perspective considers presence as process of exchange and a natural embodied response to environmental stimuli (Ijsselteijn & Riva, 2003). From this position, I consider the ways in which the layers of presence defined by psychologists Riva and Waterworth (2015) can be used as a framework for designing artistic content for fulldome space. Whilst existing research into presence favours measuring user experience through retrospective surveys and questionnaires, this paper proposes an alternate approach, which uses the layers of presence as the foundation of the creative design process.

Riva and Waterworth's (2015) ecological presence model, with its three incremental layers; core, proto and extended presence, provides valuable insight into the perceptual process of presence and offers a structure in which the psychological factors influencing presence can be considered as a starting point for designing fulldome content. The layers of presence, when mapped to three of the primary spaces of the fulldome experience: the dome theatre, the fulldome content and the viewer's perceptual experience, can be considered as incremental design stages that are mediated to progressively lead the viewer to the focused attentiveness required for maximum levels of presence.

Recent fulldome films produced by the RCA Fulldome Research Group will be reviewed to provide insights into how proto, core and extended presence can be successfully employed and integrated in designing content for fulldome spaces.

I. AN ECOLOGICAL APPROACH TO PRESENCE THEORY

I.1 Moving Beyond Telepresence

Presence has been described as 'a holy grail for immersive experience designers' (McConville, 2016) and cultivating a sense of presence is the primary goal for artists and designers working in fulldome space. Presence is multifaceted concept which defies a singular definition or unifying theory. This is due, in part, to the term being used in different ways across disciplines (Waterworth et al. 2015) but the prevailing perspective, within the context of immersive media, considers presence as a by-product of technological mediation. This reflects the dominance of a rationalist orientation within the field (Zahorik & Jenison, 1998) that has its origins in the philosophy of Descartes and views the phenomenal and physical aspects of experience as separate domains (Zahorik and Jenison, 1998).

In this context, presence is defined as a 'perceptual illusion that a mediated experience is not mediated' (Held & Durlach, 1992; Steuer, 1992; McMahon, 2003) or put more simply it is the 'perceptual illusion of non-mediation' (Lombard & Ditton, 1997). This illusion is derived from the integration of the 'technical, physiological, and psychological mechanisms' of image production methods (Grau, 2003) that ensure the viewer's attention and perceptual experience is dominated by the mediated world over the physical environment (Steuer, 1992; Murray, 1997). This notion of presence is derived from the term 'telepresence' coined by Marvin Minsky in his 1980 manifesto which sought 'that sense of 'being there'' when coupling artificial devices with human sensory mechanisms (Minsky 1980). Minsky's approach has been adopted by the International Society for Presence Research (ISPR) as the foundation of their own definitions which are categorised as first and second order presence. 'First order' presence describes the human experience of the physical world as mediated by the senses and complex perceptual processes that provide a subjective sensation of being present in an environment (ISPR, 2016). Whereas 'second order' presence occurs when a technologically mediated experience is perceived as if the technology were not involved (ISPR, 2016). Second order presence can be seen as a psychological state which occurs when technological mediation forces a viewer 'perceive two separate environments simultaneously: the physical environment in which one is actually present, and the environment presented via the medium' (Steuer, 1992).

I.2 Toward an Ecological Definition of Presence

In contrast to the rationalist orientation adopted by the ISPR, an alternate approach to presence theory has emerged in parallel and is based on the ecological psychology of J.J. Gibson (Zahoric & Jenison, 1998; Waterworth et al., 2015; Giannachi et al., 2012).

James J. Gibson's ecological paradigm defines an approach to visual perception which culminated in his 1979 book 'The Ecological Approach to Visual Perception'. Gibson broke with mainstream psychological thinking, rejecting dualism in any form and emphatically declaring that mind, matter, body and the awareness of 'one's complementary relations to the world are not separable' (Gibson,1979). Gibson dismissed the idea of the mind as a separate organ, which operated upon bodily sense data and argued that perception is not the achievement of a mind in a body, but of the organism as a whole in its environment (Ingold, 2000).

Adopting Gibson's ecological perspective, psychologists Pavel Zahoric and Rick L. Jenison (1998) view the mind, body, and environment as entwined in a dynamic, direct, continuous inseparable interaction. From this ecological position, presence is considered a natural embodied response to environmental stimuli, which is equally mediated 'by both physical (our body, technological devices, etc.) and conceptual tools which belong to a given culture' (Ijsselteijn & Riva, 2003). In this sense, presence is not limited to a technical 'illusion of non-mediation' (Lombard & Ditton, 1997), instead it can be defined as an encompassing 'ecological process that marks a moment of awareness of the exchanges between the subject and the living environment of which they are part' (Giannachi et al. 2012). Psychologists Giuseppe Riva and John A. Waterworth, take this definition further by identifying three layers within the process of presence.

I.3 The Layers of Presence

Riva and Waterworth define presence through an incremental three-layer structure consisting of proto presence, core presence and extended presence (2015). This structure reflects established psychological models of development of the self and the first of these layers 'proto presence' can be seen as 'the fact of existing or being present' (Oxford Dictionary, 2016). It is a largely non-conscious process which considers the physical self as separate from the non-self (Waterworth et al., 2015). 'Core presence' moves to a conscious real-time process which can be understood as the relationship of the self to the present world (Riva et al., 2015). This layer equates to the levels of presence experienced in the 'perceptual illusion of non-mediation' or telepresence. The third layer, 'extended presence' is a conscious understanding of the self as an integral part of present external world, in which experiences are verified in relation to their value and significance for the observer. (Waterworth et al., 2015). Extended presence reflects the interconnected relationality of Gibson's ecological paradigm.

Riva and Waterworth (2015) propose that maximum presence occurs when these three layers are integrated and suggest that it is possible to train the tendency for increased levels of presence through appropriate design. When the layers of presence coalesce within effectively designed virtual spaces they have 'the capacity to evoke powerful emotional experiences' (Waterworth et al., 2015).

II. THE LAYERS OF PRESENCE IN FULLDOME SPACE

II.1 The Primary Spaces of Fulldome

In order to mediate a rich, evocative and engaging immersive experience which cultivates maximum presence, proto, core and extended presence must coalesce. In fulldome space these three layers can be seen to correspond to three of the four primary spaces which underpin the fulldome experience. These four primary spaces are defined as the dome theatre, the media content, the perceptual space of the viewer and the emergent infinite space of the fulldome experience (French & Spanou, 2016).

II.2 Mapping the Layers of Presence into Fulldome Space

Proto presence can be seen to map to the structure of the dome theatre and relates to the quality of the experience within the physical space of the dome. Design at the level of proto presence includes elements such as seating, projection brightness, contrast, resolution, alignment and audio quality. To achieve a sense of presence at this level the physical and technical aspects of the fulldome experience must integrate seamlessly.

As the viewer becomes orientated within dome theatre and their sense of being immersed in the space increases, core presence is initiated. At this stage, design elements such as lighting, dark adaption strategies and pre-show content (audio and video) can be used to transition the viewer's perceptual attention from the physical experience of the dome toward the media content. This transition is critical as it the point at which the viewer shifts from an exocentric to an egocentric spatial strategy. The viewer's body becomes the frame of reference, in contrast to exocentric strategies based on external structures in the environment (Schnall et al. 2012). This is a fundamental factor which differentiates the fulldome experience from other media environments. Fulldome space is not a picture we observe remotely through a rectilinear frame, it is an encompassing embodied spherical experience. In this sense, fulldome space reflects Gibson's worldview, placing the body at the centre of 'an environment that surrounds one, that is everywhere equally clear, that is in-the-round, and that is all-of-a-piece' (Gibson, 1979). Designing for core presence in the egocentric spatial strategy of fulldome space requires a unique approach to visual composition, editing and sound design. The set of design principles for visual storytelling in fulldome outlined in NSC Creative's Domography (Bradbury, 2016) provide an effective framework to ensure the viewer's gaze is led towards the key elements of the narrative (ibid.). For core presence to be fully experienced it is critical that the viewer's attention be continually directed toward the media content such that the 'perceptual illusion of non-mediation' (Lombard & Ditton, 1997) is able to occur.

When the viewer's sensory perception, spatial strategies and locus of attention are fully engaged in the immersive media content, the final layer of extended presence becomes possible. The framelessness and expanded field of view when combined with spatial mapping intensify cognitive experiences in fulldome space (Schnall et al. 2012). This expanded perceptual experience serves as a trigger for extended presence. As the physical structure of the dome appears to fall away the viewer perceives themselves as an integral and interconnected part of the world presented within the fulldome media. Perceptually, this is equivalent to a natural embodied response to the environmental stimuli but in this case, presence occurs in response to the immersive mediated world. Research suggests that extended presence is more likely to happen when the narrative content affords the viewer personal significance or value (Riva et al, 2015).

III. THE LAYERS OF PRESENCE AS THE FOUNDATION OF FULLDOME DESIGN

III.1 The Challenge of Designing for Extended Presence

Designing for extended presence in fulldome space is a challenging proposition, as it is highly subjective and relies upon proto and core presence as pre-cursors to the experience. However, this challenge forms one of the research themes adopted by the RCA Fulldome Research Group (FDRG) in their investigation of the creative and artistic possibilities of fulldome space. The following review of selected recent films by the FDRG offers insights into some of the ways the layers of presence can be used to design fulldome content that invites extended presence. This discussion will focus on extended presence as it assumes prior understanding of design strategies used to elicit presence at the proto and core levels.

III.2 The Space Between Image and Sound

In addressing this design challenge, it is useful to consider specific aspects of the fulldome experience. Within conventional planetarium shows and in science communication more broadly sound is often used as a way to explain the images on screen and provide factual information for the viewer. Whilst this approach is very successful in an educational context, it can limit sensory engagement for the fulldome viewer, as often they are told what and how to think about the content they see. Two recent FDRG films use sound in another way to invite a more active participation with the viewer in order to move from core toward extended presence. In Michaela French's film 'The Light of Home' (2016) (see Figure 1), sound and image explore the theme of the experience of light, but one does not try to illustrate the other. Rather, the two elements work independently of one another and are merged only in the viewer's perceptual experience. In this way, the viewer enters into an exchange with the mediated content and becomes aware of themselves as an active participant in this environment. The multi-layered audio track is designed as 5.1 surround sound and the use of spatial sound brings the content into play with the viewer's egocentric spatial strategies by locating layers and moments of sound at specific points across the dome environment. In this way, the emphasis and interpretation of the film becomes a personal experience for each viewer that reflects a real world ecological engagement.

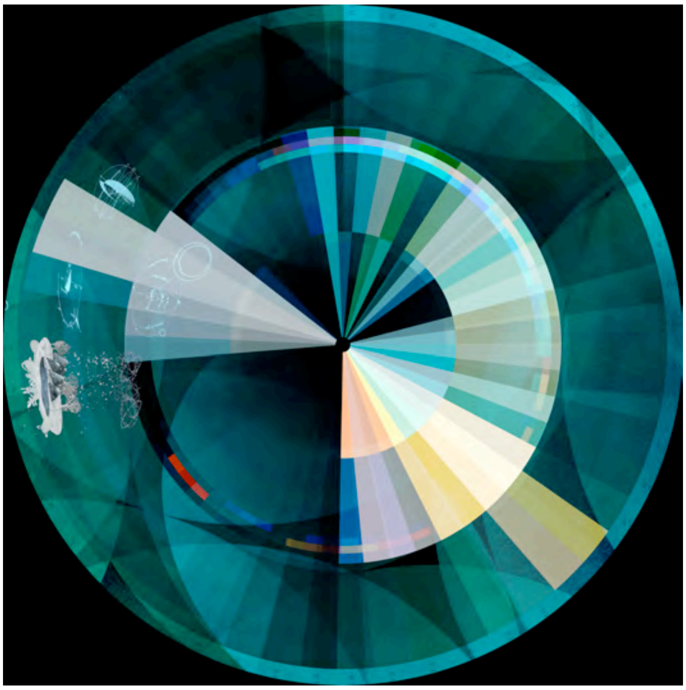

Figure 1 – Still from *The Light of Home* (2016) by Michaela French

III.3 Seeing the Process of Seeing

Emily Briselden-Waters employs sound and image as separate elements in her film ‘Circus of Anxiety’ (2016) (see Figure 2) to build a sense of tension in the work. The film also adopts an additional multi-sensory strategy to bring the viewer into a direct relationship with the film. ‘Circus of Anxiety’ aims to communicate the experience of anxiety to the viewer through strongly contrasted black and white images and abrupt edits. At times, this technique leaves an afterimage burnt onto the viewer’s retina, ensuring a direct physical interaction with the film which combines with a moment of awareness of the viewer’s own process of visual perception. Again, this approach moves beyond core presence and the’ illusion of non-mediation’ to invite the viewer into an experience of extended presence through an awareness of an exchange in their own process of seeing.

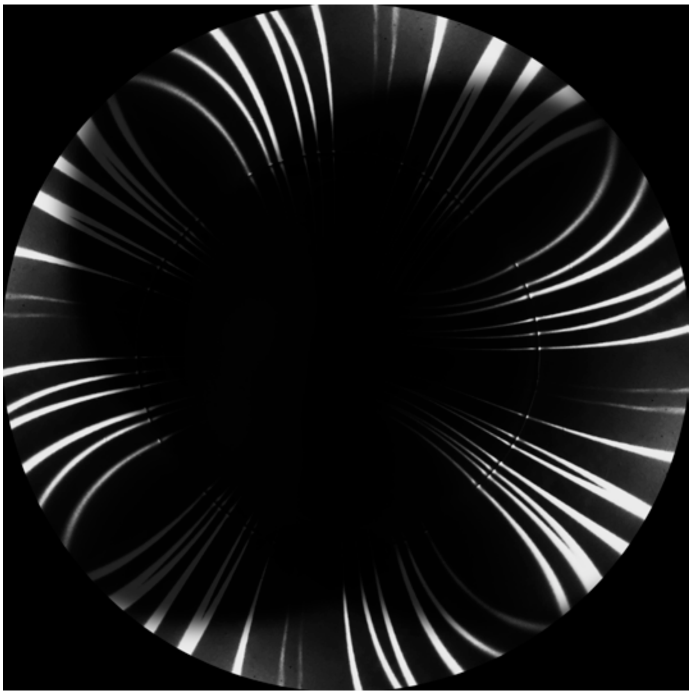

Figure 2 – Still from *Circus of Anxiety* (2017) by Emily Briselden-Waters.

III.4 Movement, Space and Distance

As previously discussed, successfully leading the viewer’s gaze is a critical aspect of fulldome design (Bradbury, 2016). Two films by Kelly Spanou, achieve this by using movement and spatial design to fully engage the viewer in the mediated world of the fulldome content. In the films ‘Apeiron’ (2015) and ‘Sonar’ (2016) (see Figure 3), Spanou creates expanded space and depth by distorting and stretching structured layers in multiple directions. As selected layers draw downward, they anchor the viewer's body to the ground, whilst other layers simultaneously lift upward into an imagined celestial sphere. This stretching and expanding of space secures the viewer's locus of attention and successfully leads them to perceive not only the mediated world in the projection but worlds beyond worlds that extend from their own body outward to the infinite. Once again, this awareness of the exchanges between the viewer and the environment enable the transition from core presence into the experience of extended presence.

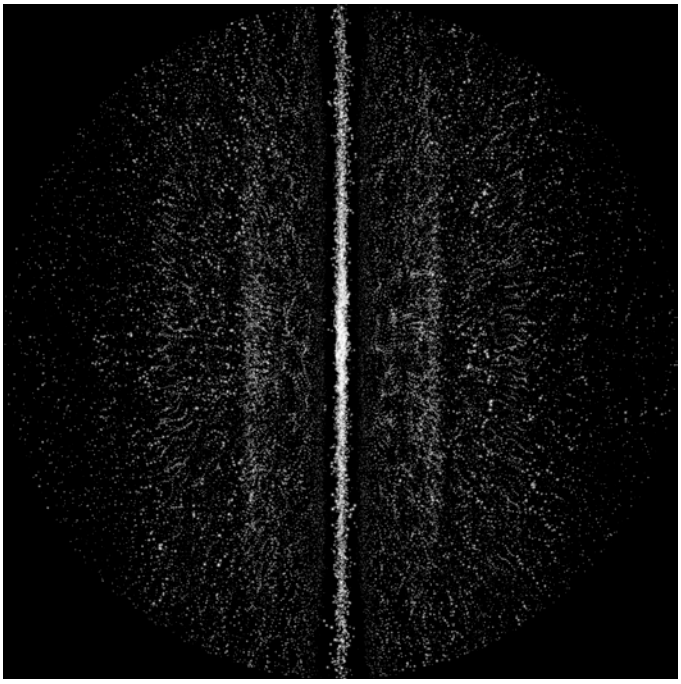

Figure 3 – Still from *Sonar* (2016) by Kelly Spanou.

III.5 Extending the Layers of Presence

The progression from proto to core to extended presence has been shown to offer an effective approach in designing evocative, immersive and engaging experiences in fulldome space. However, in a recent FDRG dome project, commissioned for the Victoria and Albert Museum, designing with the layers of presence as a progressive framework was not possible because of the context in which the work was presented.

'Climate Crimes' (2018) (see Figures 4 & 5) is an artisitc research-based fulldome installation by Dr Adrian Lahoud, Michaela French and Kamil Dalkir. The dome, which is constructed of ninety-six curved triangular panels, is suspended at the centre of the V&A's 'The Future Starts Here' exhibition. The dome is open to the exhibition space and the joints, seams and projectors are exposed as deliberate elements of the work. There is no illusion of non-mediation possible in this situation. Designing the work therefore required an alternative approach, but presence remained a primary goal.

'Climate Crimes' investigates the complex relationship between human migration and climate change. The media content combines contemporary global data visualisations, video footage of climate summits and refugee migration and artistic digital animation with voiceover and textured surround sound. The work uses the layers of presence to invite the viewer to experience the complexity of this real-world situation, but in this case, the layers operate in a different way. The sight of the projected dome suspended in the gallery space ensures proto presence as an experiential foundation. The visual complexity, the expansion and contraction of space from micro to human to global scales, the flow of movement, and integration of sound and image discussed in the earlier examples, are all used to focus attention in this work and enable the viewer's transition toward core presence.

Climate change and migration are presented not as abstract data sets and statistics, but as part of the ecological exchange in the viewer's world. The content reflects the complexity of these subjects, and invites the viewer to the see the highly-mediated political, economic and cultural narratives that surround these issues. In the 'Climate Crimes' project, extended presence is very unlikely to occur within the fulldome space because of the presentation context, rather, it unfolds as an external experience in which the viewer becomes more aware of their individual relationship to the complex global challenges of migration and global warming. In this case, the viewer's experience aligns to the previously stated definition of presence as an 'ecological process that marks a moment of awareness of the exchanges between the subject and the living environment of which they are part' (Giannachi et al., 2012).

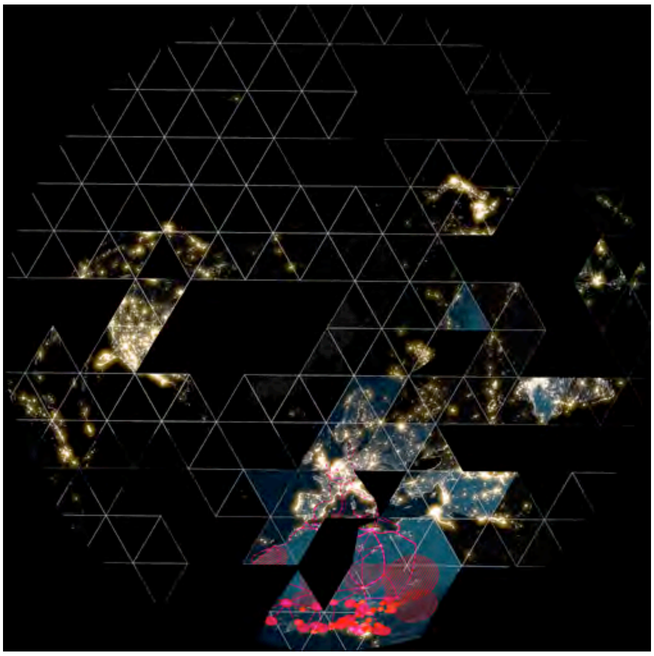

Figure 5 – Still from *Climate Crimes* (2018) by Michaela French, Adrian Lahoud and Kamil Dalkir. / Figure 6 – *Climate Crimes* (2018) fulldome installation at the Victoria and Albert Museum.

IV.CONCLUSION

By adopting an ecological foundation based on J.J Gibson's psychological paradigm, the definition of presence can be expanded beyond telepresence and the illusion of non-mediation to incorporate a broad perceptual and cognitive exchange, that has the capacity to evoke rich emotional and engaging experiences. The fulldome experience itself can be seen as ecological when the dome space, the technology, the medium and the viewer's perceptual experience coalesce to bring about states of presence.

It has been shown in this paper how the layers of presence; proto, core and extended, can be used as a foundation for creating artistic content in fulldome space. The discussion of selected films by the RCA Fulldome Research Group, provides detailed insights into the ways artists employ the layers of presence to engage the viewer by mediating multi-sensory composition, ego-centric spatial strategies, temporal and narrative movement, and locus of attention. This approach allows the designer to enhance the sense of immersion, illusion and engagement in the fulldome space and culminates in a unified embodied experience which has the potential to elicit maximum levels of presence through structured artistic practice.

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Colors from Space - Planetarium Activities for Successful Shows

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BIOGRAPHY

Alan Gould worked for the Lawrence Hall of Science Planetarium 1974-2013 and was its Director 1998-2009. He was Co-Investigator for EPO for the NASA Kepler mission from 2001-2013. He was president of the Pacific Planetarium Association, is currently its Treasurer/Secretary, and is IPS Webmaster. More info: http://www.uncleal.net/alan.

ABSTRACT

Planetarium Activities for Successful Shows (PASS) has planetarium activities for live presenters to engage audiences in vivid learning experiences. For example, in the show Colors from Space, the audience explores what can we learn about the stars and planets from colors. To get an understanding of why we see color, the audience observes how the colors of objects change as they "travel" to imaginary planets circling a red sun, a green sun, and a blue sun. More activities are on the PASS website: http://www.planetarium-activities.org. PASS shows have been adapted for especially easy use by users of these systems: Digitarium, Sky-Skan, and Evans & Sutherland.

INTRODUCTION

This session is a segment from the planetarium show Colors from Space (http://www.planetarium-activities.org/shows/cs), from the series Planetarium Activities for Successful Shows (PASS; cover in Figure 1).

Figure 1 – The cover of the presenter's guide for the Colors from Space planetarium show

I. LOOKING FOR COLORED STARS

The show starts out with the audience looking for different color stars in the night sky and then imagining what it might be like to live on a world immersed in a single color of light, for example red, blue, or green.

We then fill the planetarium with color, starting with red. With fulldome video, this can be easily done by creating a graphic consisting of a pure color to project through the system. Three-color cove lighting systems can work also. For the original show (pre-1990), we made a light system of three colored dichroic lights with Medium Red (RoscoLux #27) Kelly Green (#94) Medium Blue (#88) filters.

II. WHAT COLOR ARE YOUR BLUE JEANS?

With the planetarium filled with red light, we ask the audience to look a the clothes of their neighbors.
What color do blue jeans look? [They look black or very dark.]
What color does a red blouse, shirt, or other object look? [They are a very light color.]
When the planetarium is filled with only blue light, the audience sees that the appearance of those same objects is reversed: blue things look light colored and red things look dark. Why is that?

It all has to do with whether light is reflected or absorbed by an object. Red objects reflect red light and absorb other colors. So when we have the planetarium filled with red light, the red objects reflect that light and the light gets to our eyes, so the object looks light colored. Blue objects absorb the red light, no light gets to our eyes, and so the object appears black or dark.

When the planetarium is filled with blue light, the opposite condition exists. Red objects absorb the blue light so they look dark. Blue objects reflect the blue light, so they look light colored.

III. THE MAGIC CLOTH

With this knowledge of the meaning of absorption and reflection of light and the appearance of colored objects illuminated by different colors of light, we proceed to look at an interesting pattern on a piece of cloth (or paper).

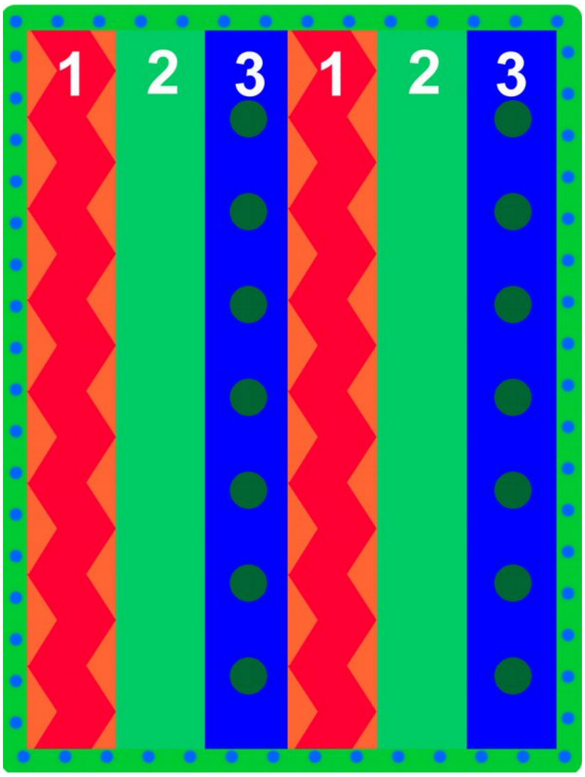

Figure 2 – The Magic Cloth pattern

With the planetarium filled with only red light, we distribute a paper version of what in the original show was a "magic" cloth —lengths of cloth about 8 meters long that audience members unfurled across their laps in our 7 meter diameter planetarium with a single row of bench-style seats. The paper version works well in larger planetariums. The color pattern is shown in Figure 2.

We ask the audience to describe the pattern of colors. They can agree that there is a bright stripe that reflects red light (or looks bright under red light) and a dark stripe (or two) that absorbs it (or looks dark under red light).

Then we take the cloth to a green star and we often get gasps of astonishment.
Wow! What happened!!? It looks like a totally different piece of paper.
We ask someone to describe the new pattern. [There's a new thin zig-zag line, so there are three stripes of different widths.]

We want to discover the "true" colors of each of those stripes, and to do this we can use what we learned when we looked at our clothes under different color lights.
Does that zig-zag look bright or dark? [Dark.] That is because it must be absorbing the green light.
Is it possible that the zig-zag could be green? [No. If so, it would look bright.]
What about the background stripe that the zig-zag is on, does it look bright or dark? [Bright.]
It looks bright because it is reflecting the green light.
Is it possible that the background could be green? [Yes.] Could it be another color? [White or any light color.]
Now keep track of that zig-zag by putting your finger on it while we return to the red star to see what happens.
[Switch back to red light.]
The zig-zag disappeared! Where did it go? I told you to keep track of it!!
Now, does the area where the zig-zag is supposed to be look bright or dark? [Bright.]
The zig-zag and its background are two different colors but they are reflecting red light equally.
Is it possible the zig-zag could be red? [Yes.]
Now its background looks bright, too.
Could it be red, also? [No.]
It looks bright in both red and green light, so it probably is white, yellow, light orange or some other color that reflects both red and green. Now, put your finger on the dark stripe labelled 2.
Could this be red? [No, because it absorbs red light.]
Let's go to a green star.

[Red light off, green light on.]
The stripe looks bright.
What color do you think it could be? [Green; or maybe blue.]
If it is blue it should look brighter near a blue star: let's see.
[blue light on.]
It looks darker, therefore it's not blue, it's probably green. So far we have guessed a wide green stripe, and a red zig-zag on a white, yellow or light orange background.
What color could the stripe labelled #3 be? [It's brightest under the blue light, so it's probably blue.]
How about the dots? What color light do they show up best with?

What color light do you think we could shine on the cloth to see its real colors?
Let's see what happens when we combine colors. Look at the dome as we mix the colors:
blue + green = aqua (turquoise, cyan, or plain blue-green). red + blue = pink (or purple, or magenta)
green + red = yellow
Finally
red + green + blue = WHITE!! White light is made from all colors mixed together. Look at your clothes now. And now we can see the "true" colors of the cloth and we find that we were correct in our guesses.

IV. CONCLUSION

In summary, we can say that an object looks brightest when illuminated by light of the same or nearly the same color (because the object reflects the light), and looks dark when illuminated by a light of very different color (because the object absorbs the light). Pale colors and white look bright in any color light, and dark colors like black, or brown, look dark in any color light. The red zig-zag and its pale orange background looked equally bright in the red light. In fact we could not tell they were different and that's what made the zig-zag disappear. On the other hand, in blue or green light the red became very dark, while the pale background remained bright. This is because light striking an object is either reflected into our eyes, or absorbed. Objects reflect mostly the color light that they appear to be, and absorb all other colors.

The Colors from Space show is about physics of light and color.
An excerpt from Colors From Space show script for the section titled "The Magic Cloth may be found on this web page - http://www.planetarium-activities.org/activities/categories/miscellaneous/the-magic-cloth

A summary of all the PASS programs can be found at http://www.planetarium-activities.org/shows/pass-descriptions and PASS flier is in Figure 3.

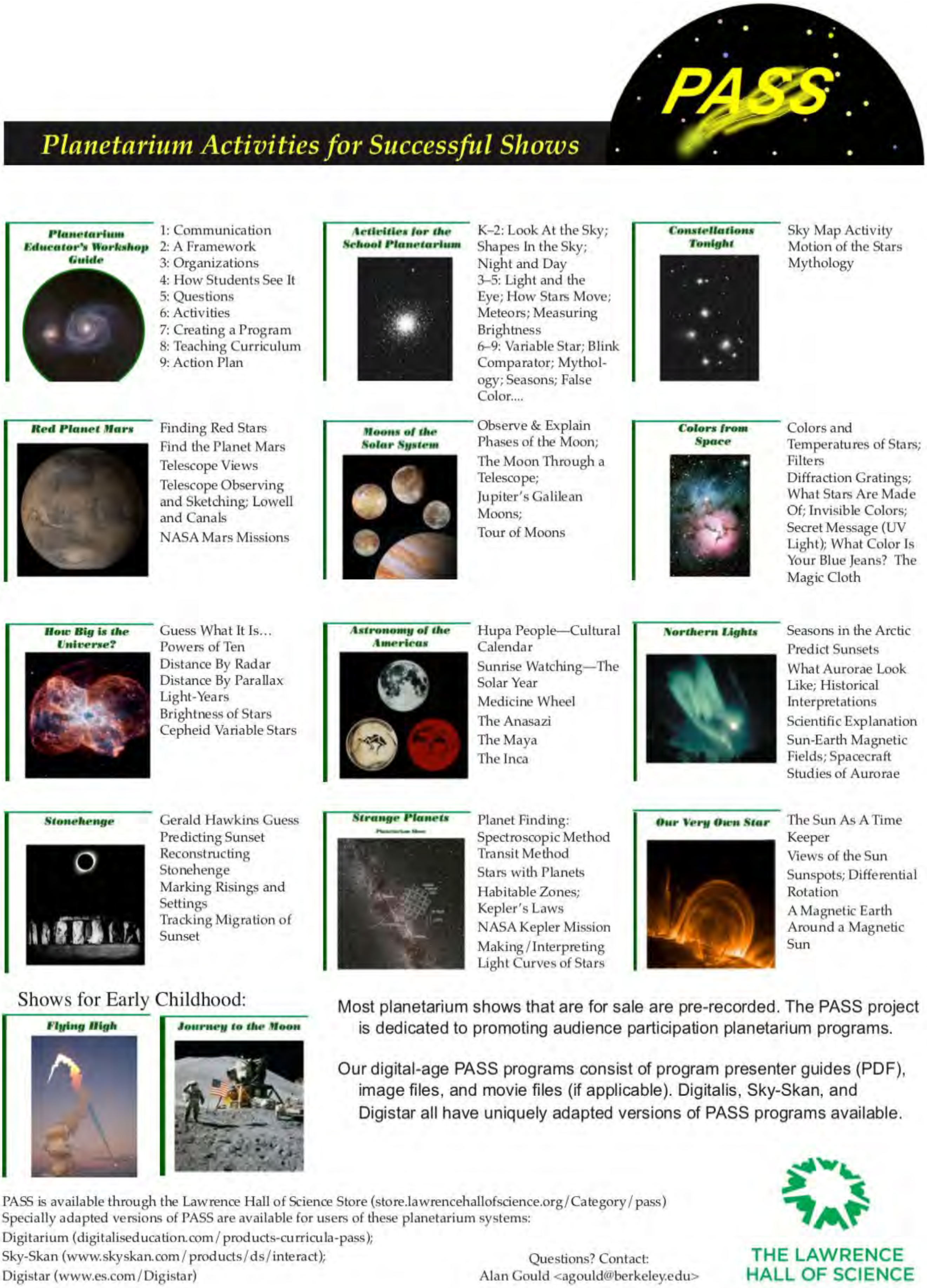

Figure 3 – PASS Flier

ACKNOWLEDGMENTS

The following staff members of the Lawrence Hall of Science Astronomy and Physics Education Project tested the first version of Colors from Space: Bryan Bashin, Cynthia Carilli, Cathy Dawson, Stephen Gee, Mark Gingrich, Cheryl Jaworowski, and Bob Sanders.

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REFERENCES

Planetarium Activities for Successful Shows (PASS) website - http://www.planetarium-activities.org/

IPS web page - Resources for presenting live, interactive planetarium shows - https://www.ips-planetarium.org/page/lips

Multi-discipline Interactive Programs Under the Dome I

Talk 1 : Colors from Space - Planetarium Activities for Successful Shows

Alan Gould, *Lawrence Hall of Science, University of California, Berkeley*
Email: agould@berkeley.edu

BIOGRAPHY

Alan Gould worked for the Lawrence Hall of Science Planetarium 1974-2013 and was its Director 1998-2009. He was Co-Investigator for EPO for the NASA Kepler mission from 2001-2013. He was president of the Pacific Planetarium Association, is currently its Treasurer/Secretary, and is IPS Webmaster. More info: http://www.uncleal.net/alan.

ABSTRACT

Planetarium Activities for Successful Shows (PASS) has planetarium activities for live presenters to engage audiences in vivid learning experiences. For example, in the show Colors from Space, the audience explores what can we learn about the stars and planets from colors. To get an understanding of why we see color, the audience observes how the colors of objects change as they "travel" to imaginary planets circling a red sun, a green sun, and a blue sun. More activities are on the PASS website: http://www.planetarium-activities.org. PASS shows have been adapted for especially easy use by users of these systems: Digitarium, Sky-Skan, and Evans & Sutherland.

INTRODUCTION

This session is a segment from the planetarium show Colors from Space (http://www.planetarium-activities.org/shows/cs), from the series Planetarium Activities for Successful Shows (PASS; cover in Figure 1).

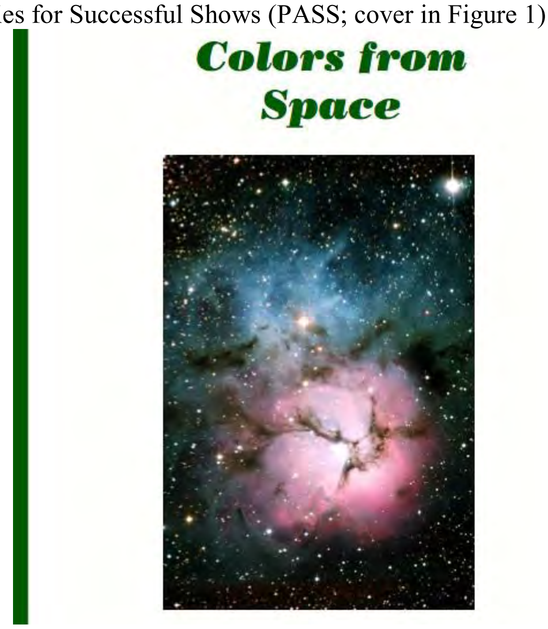


Figure 1 – The cover of the presenter's guide for the Colors from Space planetarium show

I. LOOKING FOR COLORED STARS

The show starts out with the audience looking for different color stars in the night sky and then imagining what it might be like to live on a world immersed in a single color of light, for example red, blue, or green.

We then fill the planetarium with color, starting with red. With fulldome video, this can be easily done by creating a graphic consisting of a pure color to project through the system. Three-color cove lighting systems can work also. For the original show (pre-1990), we made a light system of three colored dichroic lights with Medium Red (RoscoLux #27) Kelly Green (#94) Medium Blue (#88) filters.

II. WHAT COLOR ARE YOUR BLUE JEANS?

With the planetarium filled with red light, we ask the audience to look a the clothes of their neighbors.
What color do blue jeans look? [They look black or very dark.]
What color does a red blouse, shirt, or other object look? [They are a very light color.]
When the planetarium is filled with only blue light, the audience sees that the appearance of those same objects is reversed: blue things look light colored and red things look dark. Why is that?

It all has to do with whether light is reflected or absorbed by an object. Red objects reflect red light and absorb other colors. So when we have the planetarium filled with red light, the red objects reflect that light and the light gets to our eyes, so the object looks light colored. Blue objects absorb the red light, no light gets to our eyes, and so the object appears black or dark.

When the planetarium is filled with blue light, the opposite condition exists. Red objects absorb the blue light so they look dark. Blue objects reflect the blue light, so they look light colored.

III. THE MAGIC CLOTH

With this knowledge of the meaning of absorption and reflection of light and the appearance of colored objects illuminated by different colors of light, we proceed to look at an interesting pattern on a piece of cloth (or paper).

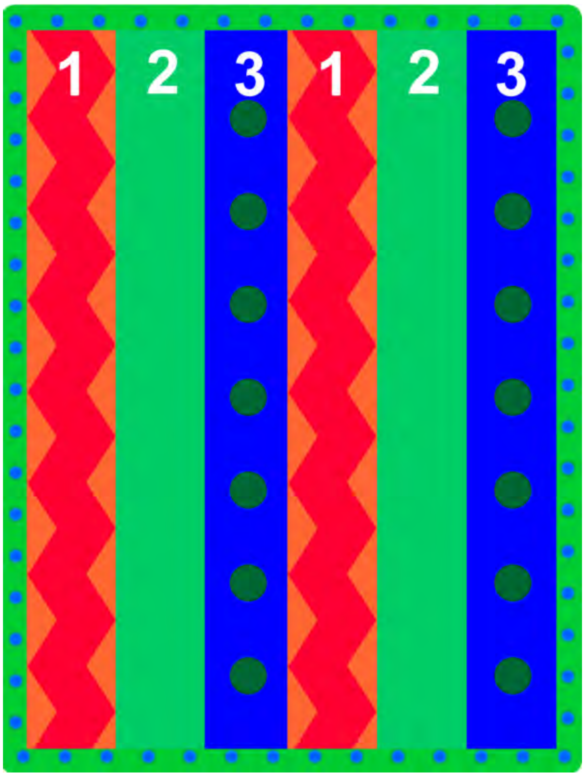


Figure 2 – The Magic Cloth pattern

With the planetarium filled with only red light, we distribute a paper version of what in the original show was a "magic" cloth—lengths of cloth about 8 meters long that audience members unfurled across their laps in our 7 meter diameter planetarium with a single row of bench-style seats. The paper version works well in larger planetariums. The color pattern is shown in Figure 2.

We ask the audience to describe the pattern of colors. They can agree that there is a bright stripe that reflects red light (or looks bright under red light) and a dark stripe (or two) that absorbs it (or looks dark under red light).

Then we take the cloth to a green star and we often get gasps of astonishment.
Wow! What happened!!? It looks like a totally different piece of paper.
We ask someone to describe the new pattern. [There's a new thin zig-zag line, so there are three stripes of different widths.]

We want to discover the "true" colors of each of those stripes, and to do this we can use what we learned when we looked at our clothes under different color lights.
Does that zig-zag look bright or dark? [Dark.] That is because it must be absorbing the green light.
Is it possible that the zig-zag could be green? [No. If so, it would look bright.]
What about the background stripe that the zig-zag is on, does it look bright or dark? [Bright.]
It looks bright because it is reflecting the green light.
Is it possible that the background could be green? [Yes.] Could it be another color? [White or any light color.]
Now keep track of that zig-zag by putting your finger on it while we return to the red star to see what happens.
[Switch back to red light.]
The zig-zag disappeared! Where did it go? I told you to keep track of it!!
Now, does the area where the zig-zag is supposed to be look bright or dark? [Bright.]
The zig-zag and its background are two different colors but they are reflecting red light equally.
Is it possible the zig-zag could be red? [Yes.]
Now its background looks bright, too.
Could it be red, also? [No.]
It looks bright in both red and green light, so it probably is white, yellow, light orange or some other color that reflects both red and green. Now, put your finger on the dark stripe labelled 2.
Could this be red? [No, because it absorbs red light.]
Let's go to a green star.
[Red light off, green light on.]
The stripe looks bright.
What color do you think it could be? [Green; or maybe blue.]
If it is blue it should look brighter near a blue star: let's see.
[blue light on.]
It looks darker, therefore it's not blue, it's probably green. So far we have guessed a wide green stripe, and a red zig-zag on a white, yellow or light orange background.
What color could the stripe labelled #3 be? [It's brightest under the blue light, so it's probably blue.]
How about the dots? What color light do they show up best with?

What color light do you think we could shine on the cloth to see its real colors?
Let's see what happens when we combine colors. Look at the dome as we mix the colors:
blue + green = aqua (turquoise, cyan, or plain blue-green). red + blue = pink (or purple, or magenta)
green + red = yellow
Finally
red + green + blue = WHITE!! White light is made from all colors mixed together. Look at your clothes now. And now we can see the "true" colors of the cloth and we find that we were correct in our guesses.

IV.CONCLUSION

In summary, we can say that an object looks brightest when illuminated by light of the same or nearly the same color (because the object reflects the light), and looks dark when illuminated by a light of very different color (because the object absorbs the light). Pale colors and white look bright in any color light, and dark colors like black, or brown, look dark in any color light. The red zig-zag and its pale orange background looked equally bright in the red light. In fact we could not tell they were different and that's what made the zig-zag disappear. On the other hand, in blue or green light the red became very dark, while the pale background remained bright. This is because light striking an object is either reflected into our eyes, or absorbed. Objects reflect mostly the color light that they appear to be, and absorb all other colors.

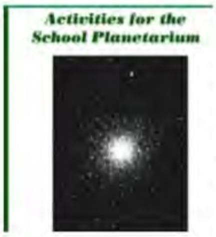
The Colors from Space show is about physics of light and color.
An excerpt from Colors From Space show script for the section titled "The Magic Cloth may be found on this web page - http://www.planetarium-activities.org/activities/categories/miscellaneous/the-magic-cloth

A summary of all the PASS programs can be found at http://www.planetarium-activities.org/shows/pass-descriptions and PASS flier is in Figure 3.

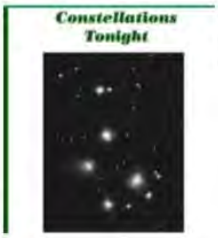
PASS

Planetarium Activities for Successful Shows

1: Communication
2: A Framework
3: Organizations
4: How Students See It
5: Questions
6: Activities
7: Creating a Program
8: Teaching Curriculum
9: Action Plan

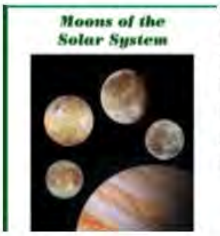


K–2: Look At the Sky; Shapes In the Sky; Night and Day
3–5: Light and the Eye; How Stars Move; Meteors; Measuring Brightness
6–9: Variable Star; Blink Comparator; Mythology; Seasons; False Color....



Sky Map Activity
Motion of the Stars
Mythology

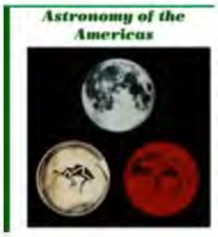
Finding Red Stars
Find the Planet Mars
Telescope Views
Telescope Observing and Sketching; Lowell and Canals
NASA Mars Missions



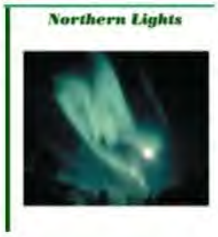
Observe & Explain Phases of the Moon;
The Moon Through a Telescope;
Jupiter's Galilean Moons;
Tour of Moons

Colors and Temperatures of Stars; Filters
Diffraction Gratings; What Stars Are Made Of; Invisible Colors; Secret Message (UV Light); What Color Is Your Blue Jeans? The Magic Cloth

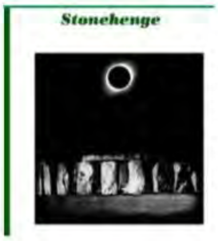
Guess What It Is…
Powers of Ten
Distance By Radar
Distance By Parallax
Light-Years
Brightness of Stars
Cepheid Variable Stars



Hupa People—Cultural Calendar
Sunrise Watching—The Solar Year
Medicine Wheel
The Anasazi
The Maya
The Inca



Seasons in the Arctic
Predict Sunsets
What Aurorae Look Like; Historical Interpretations
Scientific Explanation
Sun-Earth Magnetic Fields; Spacecraft Studies of Aurorae



Gerald Hawkins Guess
Predicting Sunset
Reconstructing Stonehenge
Marking Risings and Settings
Tracking Migration of Sunset

Planet Finding: Spectroscopic Method
Transit Method
Stars with Planets
Habitable Zones; Kepler's Laws
NASA Kepler Mission
Making/Interpreting Light Curves of Stars

The Sun As A Time Keeper
Views of the Sun
Sunspots; Differential Rotation
A Magnetic Earth Around a Magnetic Sun

Shows for Early Childhood:

Most planetarium shows that are for sale are pre-recorded. The PASS project is dedicated to promoting audience participation planetarium programs.

Our digital-age PASS programs consist of program presenter guides (PDF), image files, and movie files (if applicable). Digitalis, Sky-Skan, and Digistar all have uniquely adapted versions of PASS programs available.

PASS is available through the Lawrence Hall of Science Store (store.lawrencehallofscience.org/Category/pass)
Specially adapted versions of PASS are available for users of these planetarium systems:
Digitarium (digitaliseducation.com/products-curricula-pass);
Sky-Skan (www.skyskan.com/products/ds/interact);
Digistar (www.es.com/Digistar)

Questions? Contact:
Alan Gould <agould@berkeley.edu>

THE LAWRENCE HALL OF SCIENCE

Figure 3 – PASS Flier

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Talk 2 : Writing Beneath the Sky – A Universe of Dreams

Patty Seaton, *Howard B. Owens Science Center for Prince George's County Public Schools*
Email: pxts13@yahoo.com

BIOGRAPHY

I hold a B.S. in Astronomy and a M.A. in Science Education. I spent eight years in industry before beginning my career as a teacher in 1998. I have been at the Howard B. Owens Science Center planetarium for 25 years, 18 as full-time staff.

ABSTRACT

The stars have long inspired us. Gazing up at the stars evokes emotions, thoughts, and dreams. I have applied this idea of inspiration from the sky to language arts, especially poetry. Using the stars, astronomical images, and videos of astronomical events accompanied by music, 10-13 year-olds have written poetry and short narratives inspired by the planetarium environment. In this session, I will set the stage for you to write; and briefly, you will write your own thoughts as a poem or a short narrative.

INTRODUCTION

Everyone will be given a small workbook to use for this session. It contains images with spaces to write. Similar workbooks have been given to students, ages 10-13. We have 10 minutes here; my students have two hours to be submersed under the planetarium sky for inspiration. I begin the program with a brief tour of the night sky. This is followed by reading astronomy-themed poetry under the stars, pointing out the stars/constellations/Milky Way as referenced in these poems. Several poems are displayed on the dome for a discussion of poetic structure (such as rhyme, repetition, and mood).

I. IMAGES AS INSPIRATION

For my 7th grade students (11-12 year olds), our inspiration came entirely from images. I would show them four astronomical images with no explanation, and then allow 2 minutes for them to free write. Then I would show them the same four images with a scientific explanation, allowing them to free write again. The idea is that knowing the science may influence their impression of the image. Finally, students were given 10 minutes to look over their free-writes, and compose a first draft of a poem. Here is one of the images used. (You have two minutes to free-write about it in your journal.)

Figure 2 – Credits: NASA, ESA and the Hubble Heritage (STScI/AURA)-ESA/Hubble Collaboration

In the interest of time, we won't add the scientific information and free-write again. I suspect all of you already know the scientific background of this image! Keep in mind that most 11-12 year olds will not.

II. ANIMATIONS/VIDEOS AS INSPIRATION

For my eighth graders (ages 12-13), we changed the focus a little bit to how visuals and music worked together to create a mood. I had the students watch a time-lapse video of the aurora, a time-lapse video of a meteor shower, and an animation of the Milky Way/Andromeda galaxy collision. They watched each video three times, each with a different music score beneath it to set a mood. Each time they were given time to first select an emoji that matched the mood they felt while listening/observing, and then approximately two-minutes to free write. After all the videos/musical selections were complete, students were given a chance to share out their interpretations. Next they were given 10 minutes to write a brief narrative that enabled them to tell the story they felt one of the videos/animations and music selection was trying to tell!

Figure 2 – Andromeda and Milky Way collision (NASA)
Video Credit: NCSA, NASA, B. Robertson, L. Hernquist

In both examples, students used the planetarium and astronomical images/videos/animations to inspire narrative and poetic writing, a wonderful multi-disciplinary use of the planetarium

ACKNOWLEDGMENTS

This project was inspired by a collaboration with the Ensemble Galilei music group (http://www.egmusic.com/) and Prince George's County Public Schools, particularly Hyattsville Middle School.

Music used with permission from Stephen DuBois (https://stephendubois.bandcamp.com/).

Talk 3 : Stonehenge

Susan Reynolds Button
IPS Portable Planetarium Committee
sbuttonq2c@gmail.com

BIOGRAPHY

Susan Button, a retired teacher and mobile dome director, is a past president of IPS, has chaired the Portable Planetarium Committee since 1988, and has been a member of the International Relations Committee since 2017.

ABSTRACT

This presentation will be an abbreviated version of the Lawrence Hall of Science PASS program, "Stonehenge." Visitors predict where sunrises and sunsets will occur along the eastern and western horizons during different seasons. The observations are conducted in the context of judging if the English stone circle of Stonehenge could have been used by its builders as an observatory and calendar.

Cover photo from PASS program "Stonehenge"; collage elements include Solar Eclipse, courtesy of Peter Michaud and Stonehenge, courtesy of Gerald S. Hawkins.

WORKSHOP

Stonehenge is a prehistoric stone circle located in southern England. The mystery of why and how it was built is still not completely understood. Some basic understandings have developed due to the curiosity of archeologists and astronomers.

Gerald Hawkins, an astronomer, entered the positions of the standing stones and other features at Stonehenge into an early IBM 7090 computer and in 1963 he claimed that his findings showed that Stonehenge was built to serve as an astronomical observatory. Since computers were such a new technology, his findings received a great deal of attention. Although some of his claims are still in question his ideas sparked the development of a new field of study, "Archeoastronomy." Astronomers became more interested in archeology and archeologist became more interested in astronomy. And so began a more intense study of how the sky played a role in the lives of various cultures and how the structures they build may help to decode that role.

This program uses the mystery of Stonehenge to introduce, or reinforce, celestial motions and the changing position of the sun's rising and setting positions through the year as participants try to determine if Stonehenge is indeed an astronomical observatory and calendar.

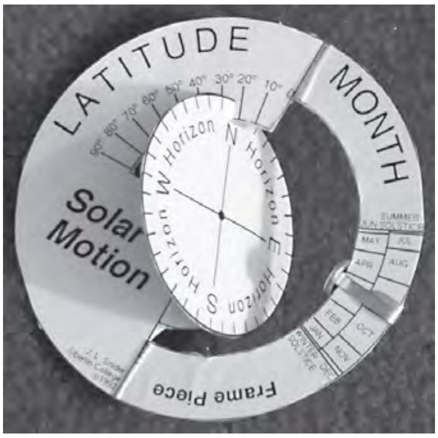
The target audiences for this program include the public and students 9 years of age and older. It is designed to highlight how new ideas arise and are tested using scientific methods. It also demonstrates how one person's ideas can have a profound influence beyond their initial intent.

The Stonehenge show first introduces how Gerald Hawkins was inspired by the fact, discovered a few hundred years ago, that on the first day of summer, the Sun as seen from the central area of Stonehenge rises almost exactly over one particular stone, now known as the "heel stone." This information led him to investigate if the other stones marked any other astronomical events. During the presentation participants are guided to follow the steps he took to validate his predictions by using a map, similar to that used by Mr. Hawkins, to reconstruct Stonehenge and using the planetarium as a "computer" to check the possible alignments.

The planetarium is set at minus 3550 years (the last major phase of Stonehenge was completed about 1550 BC), if precession available, and at latitude 51 degrees north. Students experience marking sunrise, noting noon, predicting sunset and looking at other celestial objects as possible alignments. By projecting the positions of the stone archways (Trilithons) of Stonehenge on the dome, students can test sun, moon, bright star and planet rising and setting positions to see if any celestial event can be seen through the stone openings in the archways on any particular dates. They learn that the stones could have been be used to mark the solstices.

Several supplemental activities are provided that can be used to enhance this show:

1. Azimuth and Horrizons
2. Where's East and West?
3. Creating a Horizon Sun Calendar
4. Many Moonrises
5. Solar Motion Demonstrator
6. Sunrises at Stonehenge



We will focus on just one of those activities during this workshop. We'll learn to use a simple device called a "Solar Motion Demonstrator" that will be supplied fully assembled. This device accurately models the apparent motion of the sun (rising and setting points as well as the altitude of the sun at noon) at any time of the year and any latitude in the northern hemisphere of Earth.

Since this device is designed for the Northern Hemisphere; we will discuss how it might be redesigned for the Southern Hemisphere.

Solar Motion Demonstrator from PASS Stonehenge program. Designed by Joseph L. Snider.

ACKNOWLEDGMENTS

The Solar Motion Demonstrator was designed by Professor Joseph L. Snider of Oberlin College. The design and directions for use are copyrighted by Professor Snider. You may reproduce them as needed for your own classroom or planetarium but not for commercial purposes.

REFERENCES

Planetarium Activities for Successful Shows (PASS) Stonehenge: **http://www.planetarium-activities.org/shows/sh and for other PASS programs go to: https://www.lawrencehallofscience.org/programs_for_schools/curriculum**

An IPS Clearinghouse for Live-Presenter Audience Participation Planetarium Activities

Alan Gould, John Erickson, Lawrence Hall of Science, University of California, Berkeley
Karrie Berglund, Digitalis Education Solutions, Inc.
Susan Button, Past International Planetarium Society (IPS) President
Jeanne Bishop, IPS Education Committee Chair
Email: agould@berkeley.edu

BIOGRAPHIES

Alan Gould was Director of the Lawrence Hall of Science Planetarium, UC Berkeley, from 1999 to 2009 and has been webmaster for the IPS since 2003. He is also a co-author on several programs in the Planetarium Activities for Successful shows (PASS) series. John Erickson is currently Director of the Lawrence Hall of Science Planetarium and a co-author on some of the PASS plaentarium programs.Karrie Berglund is Head of Goal #1 (professional development) of the IPS Vision 2020 task force and co-founder of Digitalis Education Soutions. Susan Button is a longtime promoter of audience participation programs, past president of IPS, and IPS Portable Planetarium Committee Chair. Jeanne Bishop is a multi-decade experience planetarium educator and IPS Education Committee Chair. Martin Ratcliffe, in addition to being past IPS President, has been active in promoting audience participation through his position at Sky-Skan. Kevin Scott has been a key driver of audience participation planetarium activities at Evans & Sutherland.

ABSTRACT

There are a growing number of websites where documentation for audience participation activities that make for exciting planetarium programs are available. The IPS website (http://www.ips-planetarium.org/) has links to sources of such activities. They have been scattered in different places: Education Resources, Planetarian archives, and Portable Planetarium Committee page. Some of the IPS affiliates, e.g. APLF, GLPA, and MAPS, have web pages for planetarium activities. A clearinghouse page is now the "Live Interactive Shows" page (/lips) with sources for activities and links for networking with similarly interested planetarians, such as Live Interactive Planetarium Symposia (LIPS) and the associated email discussion group.

INTRODUCTION

The International Planetarium Society (IPS) website has links to resources including educational activities that can be used in audience participation planetarium shows.

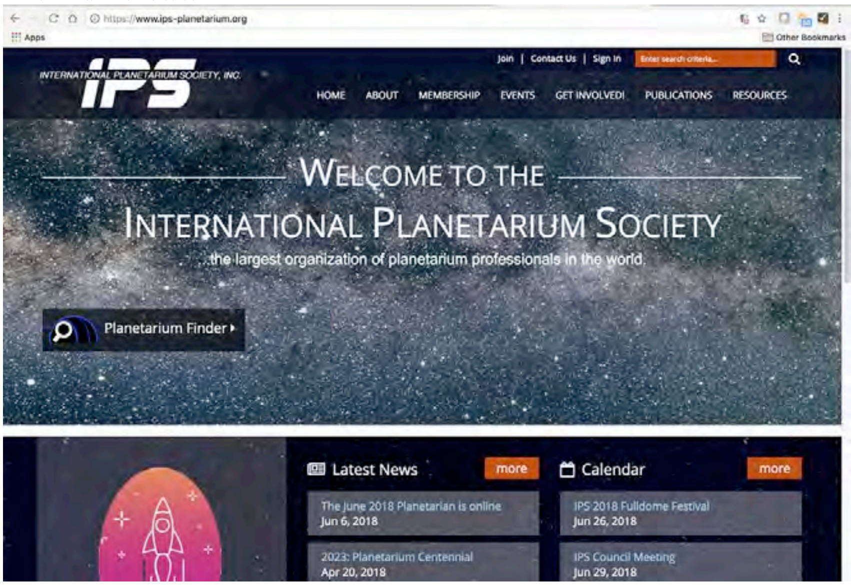


Figure 1 – IPS homepage: https://www.ips-planetarium.org

Those resources are on various related IPS pages:

- the Education Resources page (http://www.ips-planetarium.org/?page=edresources).
- the archives of the IPS journal The Planetarian (http://www.ips-planetarium.org/?page=plntrnarchive) particularly in the educational columns such as *From the Classdome*, *Lip Service*, *Mobile News*, or the IPS Education Committee column *Seeking what Works*.
- the IPS Portable Planetarium Committee has a number of activities and resources on its *Resources for Portable Planetariums* page (http://www.ips-planetarium.org/?page=portableresources). See specifically the *Portable Planetarium Handbook* for ideas about planetarium lessons.

In addition, affiliate organizations of the IPS (http://www.ips-planetarium.org/?page=affiliates) have their own websites with pages devoted to planetarium activities:

- APLF (Association des Planétariums de Langue Française - http://www.aplf-planetariums.org/),
- GLPA (Great Lakes Planetarium Association - http://glpa.org/resources), and
- MAPS (Middle Atlantic Planetarium Society - http://www.mapsplanetarium.org/category/education/).

Figure 2 – Photo from the IPS Portable Planetarium Resources web page maintained by the Portable Planetarium Committee .

Some of the prominent links on the IPS pages concerning audience participation programs are in the following sections of this poster paper.

I. PLANETARIUM ACTIVITIES FOR SUCCESSFUL SHOWS

Figure 3 – Planetarium Activities for Successful Shows resulted from a recasting of the acronym for Planetarium Activities for Student Success.

At the top of the list of hits if you aim your Internet search engine to “planetarium activities” is Planetarium Activities for Student Success (PASS), developed by Holt Planetarium staff at Lawrence Hall of Science (LHS) UC Berkeley over the years 1973–1994. National Science Foundation-funded workshops in the summer of 1978 (POP—Participatory Oriented Planetariums, with 100 planetarium educator participants) and in the summers of 1989-94 (POPS—Participatory Oriented Planetariums for Schools, with 150 participants). With the 1978 POP program, we produced Planetarium Educators Workshop Guide (IPS Special Report #10) that was distributed to all the members of the International Planetarium Society. With the POPS program we expanded Planetarium Educators Workshop Guide into the 12-volume PASS a series.

In each PASS planetarium show, visitors participate in observations, experiments, and discussion in order to experience science as exciting and understandable. They leave with feelings of accomplishment.

Titles and descriptions of all the PASS shows may be found on the PASS website - http://www.planetarium-activities.org .

Figure 4 – Students using starclocks in the planetarium. Starclock was originally part of the Sky Challenger planisphere with interchangeable star wheels for a variety of sky-watching activities.

With the advent and widespread proliferation of digital planetariums at the beginning of this millennium, we found that the audience participation principle is as valuable as ever. In furtherance of the PASS project's goal to promote audience participation in the planetarium world, PASS has established agreements with three planetarium manufacturers to adapt all of our PASS shows for each planetarium system for maximum ease of presentation by users. Those companies are the subjects in the next sections of this poster paper.

II. SKY-SKAN

The PASS series as adapted for Sky-Skan planetarium systems using Sky-Skan's DigitalSky software is called Interact! It was developed by the collaborative team of Toshi Komatsu and Alan Gould (PASS staff) and Martin Ratcliffe (Sky-Skan staff). PASS may soon be adapted for the newest version of that software, DarkMatter (https://www.skyskan.com/products/ds).

Sky-Skan

Figure 3 –In addition to having adapted PASS for DigitalSky software, Sky-Skan also has “Special Effects Discs For Classical Planetariums” that are of interest for use in audience participation programs on any platform.

III. DIGITALIS EDUCATION SOLUTIONS, INC

Digitalis® EDUCATION SOLUTIONS, INC.

Figure 4 – This manufacturer of planetarium systems has a very good section with educational activities.

On the Digitalis Education Solutions website (http://digitaliseducation.com/), the Digitalis Open Astronomy Curricula page (http://digitaliseducation.com/curricula) has a set of activities organized by grade level appropriateness. One that you can find there, for example, is especially appropriate to this time of year: Halloween Astronomy (http://digitaliseducation.com/digitalis-curricula/halloween-astronomy.pdf). It also has “augmented lessons” specifically designed for easy implementation with Digitarium planetarium systems. Among the augmented lessons are the PASS—Planetarium Activities for Successful Shows series (http://digitaliseducation.com/products-curricula-pass)

IV. DIGISTAR

Planetariums with Evans & Sutherland systems using Digistar can get PASS shows customized for Digistar through scripts that are available through the Digistar User's Group library of online scripts, media objects, and planetarium shows. These PASS resources were created by the team at Evans & Sutherland, optimized for use with their Digistar planetarium systems. (https://www.es.com).

Figure 5 – The most recent platform for which PASS has been adapted is Digistar, by Evans & Sutherland.

V. SHARING IDEAS—LIVE INTERACTIVE PLANETARIUM SYMPOSIUM (LIPS)

The first Live Interactive Planetarium Symposium (LIPS) was in August of 2011 in Bremerton, Washington, organized by Karrie Berglund and Rob Spearman of Digitalis Education Solutions, Inc. It focused on live interactive planetarium lessons, connecting a live planetarium presenter with an audience, enhancing presenter performance skills, group management techniques, and sample activities. It offered an opportunity to network and share ideas with others doing live interactive shows. There have been LIPS every year since then (see http://lipsymposium.org/LIPS/node/48 where you can find a few resources from each year). Slides from Alan Gould’s presentation on questioning strategies (The Question of Questions) at the 2011 LIPS is http://www.lipsymposium.org/LIPS/files/AlanGouldLIPS2011.pdf .

For upcoming LIPS, see http://lipsymposium.org .

Figure 6 – Logo for LIPS — Live Interactive Planetarium Symposium

We have established the main IPS clearinghouse for live presenter audience participation planetarium activities as the IPS website LIPS page (https://www.ips-planetarium.org/lips .

If you become aware of live presenter audience participation resources, please either add them to the following space in this poster or contact the author/IPS webmaster, Alan Gould agould@berkeley.edu and he will add your contributions to the growing list on the IPS LIPS page.

ACKNOWLEDGMENTS

Many thanks to:

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- Jeff Nee, Informal Education Specialist at NASA Jet Propulsion Laboratory and past Lawrence Hall of Science Planetarium presenter,

- Karrie Berglund, Head of Goal #1 (professional development) of the IPS Vision 2020 task force, co-founder of LIPS and Digitalis Education Solutions,
- Martin Ratcliffe, past IPS President and active promoter audience participation through Sky-Skan,
- The team at Evans and Sutherland that adapted PASS for Digistar.

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- IPS journal The Planetarian - http://www.ips-planetarium.org/?page=plntrnarchive
- IPS Portable Planetarium Committee - http://www.ips-planetarium.org/?page=portableresources
- APLF (Association des Planétariums de Langue Française - http://www.aplf-planetariums.org/
- GLPA (Great Lakes Planetarium Association - http://glpa.org/resources
- MAPS (Middle Atlantic Planetarium Society - http://www.mapsplanetarium.org/category/education
- Planetarium Activities for Successful Shows (PASS) website - http://www.planetarium-activities.org
- Sky-Skan - https://www.skyskan.com
- Digitalis Education Solutions Open Astronomy Curricula page - http://digitaliseducation.com/curricula
- Digitalis adaptation of PASS - http://digitaliseducation.com/products-curricula-pass
- Live Interactive Planetarium Symposium (LIPS) - http://lipsymposium.org
- IPS clearinghouse for live presenter audience participation planetarium activities: https://www.ips-planetarium.org/lips

Astronomy Olympiad
Experience from a well-functioning student competition

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BIOGRAPHIES

Tomáš Gráf was born in 1964. He graduated from Masaryk University in Brno and earned his Ph.D. in astrophysics at the same university. From 1988 to 2015, he worked at planetarium in Ostrava and now works at the Silesian University in Opava, where he is helping build a new university planetarium (to be completed in 2019).

Jan Kožuško was born in 1981. He graduated from the Czech technical university in Prague and earned his Ph.D. at Technische Universität Dresden. He worked at Observatory and planetarium in Prague and is a member of the Czech astronomical society. Since 2010 he is a president of Czech astronomy olympiad.

ABSTRACT

This poster summarizes experience gained during 15 years of existence of an astronomy competition, held in four age categories and intended for primary and secondary school students in the Czech Republic. In the Conclusion, the achievements of Czech students in the International Astronomy Olympiad (IAO) and the International Olympiad in Astronomy and Astrophysics (IOAA) are mentioned.

INTRODUCTION – HISTORY

In the Czech Republic, primary and secondary school curricula usually do not include Astronomy as an individual subject. Typically, a few areas of astronomy are covered as part of three subjects: Science, Geography, and Physics.
While olympiads in many other fields have a decades-long tradition in the Czech Republic, until recently it seemed impossible that there could be an "Astronomy Olympiad" (AO) as well.

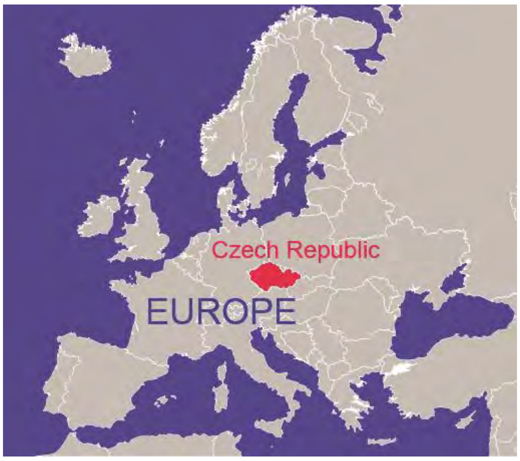

Figure 1 – Location of the Czech Republic

However, thanks to a group of amateur astronomers from the Czech Astronomy Society, it was finally established. The first Astronomy Olympiad was held in 2003/2004 in the category EF (primary level, 8th and 9th years). The pupils' interest in this competition exceeded all expectations.

Later it became apparent that the Olympiad needs to be extended to other age groups. At the same time, the organizers managed to negotiate a crucial formality: the Astronomy Olympiad was included in the "A" category of competitions officially endorsed by the Czech Ministry of Education.

After that, other institutions began participating in the organization of the competition, and new categories were established: CD (for 1st and 2nd year secondary school students; first organized in 2007/08) and then AB (for 3rd and 4th year secondary school students; first organized during the academic year 2010/11). At that time, the GH category intended for younger pupils (6th and 7th year of primary schools) was also included.

I. STRUCTURE OF THE ASTRONOMY OLYMPIAD IN THE CZECH REPUBLIC

I.1 School round

The assignment together with the solution key is available to registered teachers on the AO website. Then they choose the date for the test, evaluate the works, and submit the results via the AO website. Participants with a sufficient number of points continue to the regional round.

I.2 Regional round

The assignment can be downloaded from the AO website. The participants then send their results via e-mail to the competition organizers for evaluation. A particular fixed number of the top achievers (50 in the younger categories, 15 and 20 in the older ones) is chosen to take part in the final round. Starting from last year, this part of the competition will also include a written test (supervised by registered teachers) taking place at schools on a specified day.

I.3 Final round

Currently it takes place in Prague or Hradec Králové (category EF and GH on the same day) and Opava (category AB and CD on two different dates). The top three achievers in each category receive valuable prizes. The top finalists are selected (directly or via a special training camp) to represent the Czech Republic in international astronomy olympiads.
The process of the Czech AO is governed by the Central Committee (7 members). The main coordinator of the AO is a university lecturer from the University of West Bohemia in Pilsen.

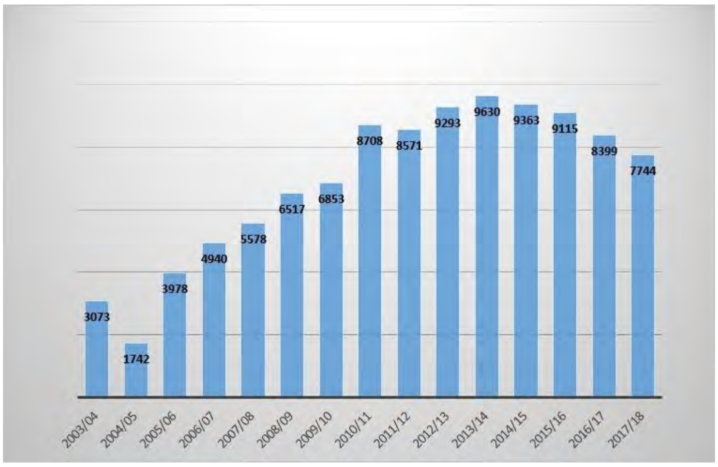

Figure 2 – Numbers of participants of Astronomy Olympiad in Czech Republic from 2003 to 2018.

II. FINANCING

Although the Czech Astronomy Society is the main organizer of the AO, the competition would not be possible without a significant support from the Ministry of Education grants and sponsors. Furthermore, the categories AB and CD are financially supported by the Silesian University in Opava throughout the academic year.

III. PARTICIPATION IN IOAA AND IAO

In recent years, a combination of different financial resources has been used to secure the funds necessary for the participation of students in two international competitions: IAO (for younger pupils and students) and IOAA (for older students).
Our students have achieved excellent results in both of these competitions.

IV. RESULTS OF CZECH STUDENTS

IV.1 International Astronomy Olympiad (IAO)

Year	Gold	Silver	Bronze	Hon. Mention
2007		1		4
2008			2	4
2009		2	3	
2011	1		1	3
2012		1	4	1
2013			3	2
2014		1	1	3
2015		1	1	3
2016		1	2	3
2017		1	1	3
Total	1	8	18	26

IV.2 International Olympiad in Astronomy and Astrophysics (IOAA)

Year	Gold	Silver	Bronze	Hon. Mention
2010	1			
2011	1	1		1
2012	2	2	1	1
2013		1	1	2
2014			2	2
2015				3
2016	1		1	3
2017		1	2	1
Total	5	5	7	13

V. INSPIRATION FOR OTHER COUNTRIES

Despite the language barrier, it would be possible to use the translated version of the already prepared assignments of the Czech AO in other countries. It is a pity that many countries do not take part in the international astronomy olympiads: a possible explanation is that they do not have their own "national" AO.

VI. CONCLUSION

The Astronomy Olympiad is currently an established science competition in the Czech Republic. Its structure is convenient for both the participants and the organizers. This fact is confirmed not only by positive feedback but also by an increasing number of participants.

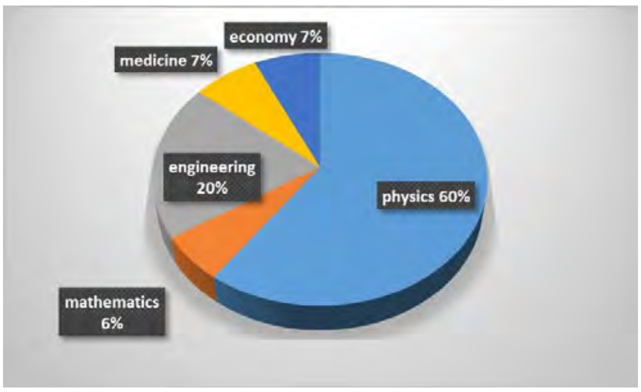

Figure 3 – Fields of follow-up study of Czech participants in international competitions IAO and IOAA from the years 2007-2013 (Kožuško 2013).

In addition, from a survey carried out among participating students it is obvious that the Astronomy Olympiad can be a great motivation for further study of scientific and technology programmes (Kožuško 2013).

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Notre Ciel : Bringing French Language Immersion to an American Planetarium

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BIOGRAPHY

Anna Green is the James S. McDonnell Planetarium Manager at the Saint Louis Science Center; where she began her career and has spent eight years engaging visitors in Space Science. She holds a B.A. in French with German and Music minors; K-12 Professional Educator License; and M.A. in Museum Studies.

ABSTRACT

In the spring of 2017, the James S. McDonnell Planetarium at the Saint Louis Science Center in Missouri presented its first ever live, interactive planetarium show completely in French, *Notre Ciel*. The importance of tying other academic subjects and real-life experiences into the subject being learned, in this case French, is important for relevancy, vocabulary growth, and showing that each discipline has a variety of applications. As informal education settings, planetariums have a unique opportunity to support students in STEaM and many additional subjects in ways that standard classrooms and pedagogical methods may not normally reach. The live French language planetarium show, presented for a group of first graders from a French language immersion school, has opened the door for the James S. McDonnell Planetarium in reaching out to a whole new audience: students learning a new language. This paper seeks to highlight what has worked and has not worked in bringing a world language under the dome and partnering with a new field trip group within schools.

Keywords: Astronomy, bilingual, English, world language, French, informal education, immersion, interactive, live, pedagogy, Second Language Acquisition

INTRODUCTION

Depending on where one lives in the world, it may not be common practice for a planetarium to present live shows in multiple languages. In the United States of America, live shows offered in multiple languages seem to be somewhat uncommon, excepting perhaps some of the planetariums in more major cities, such as Morrison Planetarium in San Francisco, California which offers live shows in four languages several times a year. One might also find an institution in a smaller town here and there with an offering in a world language as does the Chaffee Planetarium at the Grand Rapids Public Museum in Michigan with its live Spanish show; however this may not be as common. In most cases for planetaria within the USA, a show in a language other than English is often a canned production with a dubbed track in the needed language, as is the case with *The Little Star That Could* and *Dynamic Earth* in Spanish at the Bechtel National Planetarium at Columbia Basin College in Pasco, Washington, or *Big Bird's Adventure: One World One Sky* in Spanish at the Adler in Chicago, Illinois. This is an unfortunate situation as the unique environment of the planetarium can lend itself well to teaching a world language, or helping visitors who may not be comfortable outside of their own language feel more comfortable. It is within the teaching of astronomy in a world language under the dome that meaningful language learning can occur for students – giving them the opportunity to explore multiple subjects at once and outside of a normal classroom environment. With a staff member capable of presenting a live planetarium show in French, the James S. McDonnell Planetarium at the Saint Louis Science Center in the United States has presented multiple bilingual French-English live shows, and took the leap in 2017 to present the first ever all live French show, *Notre Ciel.* This paper will look at how a planetarium can be beneficial to second language acquisition, welcome visitors who do not speak English as their primary language, and increase attendance through new group visits and partnerships.

A LANGUAGE BASED BACKGROUND

Perhaps this topic seems odd coming from a planetarian, so I would like to give some context as to my credentials. Today I am the Manager of the McDonnell Planetarium in Saint Louis, Missouri, but that was not where I started. My undergraduate studies were in French, German, and Vocal Performance. I also earned a K-12 professional educator's license (PEL), with endorsements to teach French and German, which continues to remain valid. As part of the requirement for the PEL, I studied Primary Language Acquisition, and especially Second Language Acquisition (SLA) theory. My plan was to become a high school French teacher when I fell in love with volunteering at the McDonnell Planetarium. I started working in museums and began earning a Masters degree in Museum Studies to support my work at the Planetarium. I never went back to classroom teaching and eventually became a fulltime planetarian.

For a while I figured my undergraduate degree would just go mostly unused. Periodically, we might get a visitor or two who speaks French or German and I will converse with them in their native language, but otherwise my most used subject from my undergraduate studies was music due to working with the symphony in the planetarium. After a few years of working at the McDonnell Planetarium, I noticed that about once a year we seemed to have a group of French speaking students come to a show as part of a class trip abroad. Every year the teacher would speak with me and tell me that the teens did not really speak much English. I would invite them to shout out remarks in French during my show to interact if they were more comfortable but they usually stayed silent while the rest of the audience would answer my questions and pose their own in their native English. This got me wondering how to potentially not only get them more involved, but also how to bring in others who speak or are learning a world language.

WHY BRING A LANGUAGE BESIDES ENGLISH INTO THE DOME?

For students learning a world language, whether in an immersion school or in a class in a traditional school, the planetarium can provide a unique opportunity. One of the best ways to help second language (L2) acquisition is to provide meaningful input and allow the opportunity for interaction and output. According to Fred Genesee (2001) of McGill University, "Instruction for beginning language learners, in particular, should take into account their need for context-rich, meaningful environments" (para. 17). Meaningful input is language with communicative intent that is not a drill or activity specifically providing L2 learning instruction. Input is also considered in many language acquisition theories, to be the foundation for learning, comprehending and acquiring a language. By partnering with a teacher or school, a planetarium can provide meaningful input about astronomy in the L2 of the students, and in turn, provide the students an opportunity for output in a safe environment where they may not feel judged for speaking by other students. Bill VanPatten (2003) explains in *From Input to Output: A Teacher's Guide to Second Language Acquisition,* that

> it is important, however, to note that we are not talking about learners *practicing* a form of structure in their output; we are talking about learners coming to the awareness that they need a form or structure because of their output (p.69).

By asking questions and allowing the students to answer, it also provides the students the opportunity to create (hopefully meaningful) output as well, which in the end could lead to better processing of the input.

To provide the most meaningful experience for the students, the presenter should communicate with the teacher before the visit if at all possible. Students who are in the beginning stages of SLA process for meaning first and foremost, as intake processing abilities of a new language learner are limited. Intake can become a part of the linguistic system as it is what is held and processed in working memory. If there are other environmental factors drawing on the attention of the learner, however, it makes intake and processing for meaning far more difficult (VanPatten, 2003). By working with the teacher beforehand and providing suggestions for pre-visit activities, the teacher can prepare the students with vocabulary and at least some content in the classroom. This approach means students will have at least some knowledge of astronomy in the L2 so that when they hear the vocabulary and content in context, scaffolding (building upon previous instances of learning a concept) can occur and the students will be able to better process the input for meaning with less of a drain on processing resources from any other input (i.e. the stars on the dome).

A world language show is an opportunity to bring a new audience into the dome. For school based planetariums, this could be an easy fit. It gives world language instructors the opportunity to work with students in a different setting and create a fun and engaging way to teach the language, and they do not have to worry about travel costs as much as they would with a field trip outside of the school or school district. For both stand-alone planetaria and domes that are part of a museum campus, an opportunity lies within this concept. As travel is difficult for most schools, particularly if there are not multiple classes attending the trip to make the cost of bus transportation worthwhile, the potential for Science and World Language teachers to partner and bring more students is strong. Any partnerships formed could also lead to more partnerships within the same school and district as well. This is a chance for planetariums to build new partnerships with teachers too, which will hopefully increase attendance (and when applicable, revenue) and become a repeat visit every year.

There is also a benefit in regards to native speakers, as a show in their native language can make an institution feel more welcoming to them. It also enables these visitors to be better engaged and hopefully increase stay time. Furthermore, if one taps into the tourist industry in the area, it is possible to have a new group of visitors to bring in from traveling groups passing through the city. In the end this could lead to a new revenue source for the institution.

Finally, a planetarium show in a world language opens up cultural opportunities to explore with the audience. Students study their own culture, perhaps the history of other cultures within the last 500 years, and primarily that of ancient civilizations in the United States. If they are taking a world language or international studies class, they may also study current cultures of other countries. By having a world language planetarium show, students can also experience that a different culture may view science, specifically astronomy in a different way. This is the case, for example, while discussing the Big Dipper. Most American visitors who come to the planetarium are familiar with the Big Dipper, but are often unaware that other cultures call that asterism something else (i.e. the Great Plough in the U.K., *la Casserole* [the sauce pan] in France and *der Großer Wagen* [the large cart] in Germany). This lends itself to then discussing a new concept – not all star patterns are considered official constellations. This also allows for more stories from cultures other than the Greeks (which seem to be the most popular, particularly within the United States), leading to better engagement of the audience.

HOW SHOULD THE SHOW FLOW?

Once approval has been given to have a 100% live world language show (and/or a bilingual shows), decisions have to be made on how to arrange the show for the audience. Lightbown and Spada (2006) note that it is important to provide a content-based, natural setting rather than a language classroom instructional setting, and to keep in mind that that

> the focus of a lesson is… on the subject matter, such as history or [astronomy], which students are learning through the medium of the second language… the emphasis is on using the language rather than talking about it (p. 110).

By creating a planetarium show in the L2, the presenter is giving the students an opportunity to explore the language in a natural and meaningful way. The students are able to listen to, respond to and interact with the L2 in a setting where they do not have to worry about a teacher grading them on their ability to provide grammatically correct output or that they need to pass a test. Again though, presenters should remember to keep the astronomy content at the proper level for the students' age and grade, as focusing on the content and using normal L2 speech patterns will be most beneficial to them.

While one may be able to follow a normal show flow in the second language (L2), it may not be advantageous to the group in attendance. As with any live show, it is always best to gauge the audience (in advance of their arrival if possible). If the group in attendance is made up of native speakers or they have been studying the L2 for a year or more, it may be easier to provide a show in the L2 that is closer to a live show given in one's native language (L1) in terms of concepts and vocabulary. For more advanced users of the L2, (most likely older students who have had some astronomy previously in their Science courses), it may be possible to delve into more advanced topics such as the age of the universe, deep sky objects, and even black holes and quasars.

If the students in attendance are a group of novice learners, they may not have all of the necessary vocabulary to understand everything, and while content can and should be adjusted to be at the proper level of the group (VanPatten, 2003), one should not shy away from speaking normally. Beginning Astronomy topics can be covered even if the students know them in the L1 because this will give them an advantage for processing input, negotiating how the input is received, and producing meaningful output. Lee and VanPatten (2003) further these ideas, noting that communication in the L2 that is in person is helpful as

> Comprehensible input derived from interaction, then, may be quite different from, say, input from the radio or the TV, where the speaker *is* in absolute and complete control of both what is said and how it is said, and the learner has no opportunity to negotiate comprehension (p. 32).

This also means that the presenter needs to be aware of the audience's responses (or lack thereof). Checking for comprehension with questions is always a good idea to ensure that the subject matter makes sense to the learner. If needed, circumlocution, the act of using a longer, more descriptive phrase to get a point across, rather than a shorter phrase with more advanced vocabulary, can be used to aid comprehension too.

It should be kept in mind too that students are most likely still new to the ideas presented in a planetarium, and that their L2 abilities may very well be limited, so grace is required. Lightbown and Spada (2006) remind educators that "In these situations the emphasis is on getting meaning across clearly, and more proficient speakers tend to be tolerant of errors that do not interfere with meaning" (p. 111). Therefore the presenter should not take it upon themselves to correct the language, but rather just allow for use of the language in a content-rich setting. Furthermore, the presenter should be sure to give plenty of wait-time, perhaps even longer than one would normally wait for visitors in an L1 show to respond, for the visitors to answer any questions posed to them in the L2. This is due to needing time to access and activate vocabulary and grammar in the L2 which comes slower than it would in their L1 (VanPatten, 2003).

While it is best to provide input only in the target L2 and accept output in the L2 as well, if the show is bilingual one will not have that luxury. In a bilingual show situation, saying every single phrase in both languages is not necessary. While some repetition between the languages may occur, if meaning can be perceived in both languages through context, then a cadence of switching back and forth without as much direct translation may be achievable. It is good to encourage the visitors learning an L2 to respond only in the L2 and not in the L1, even if a question was posed in the L1. While not an ideal situation, this will at least give them the opportunity to practice using the vocabulary (and the presenter can respond in the affirmative both in the L2 and L1 if desired to encourage continued L2 usage).

LESSONS LEARNED FROM THE MCDONNELL PLANETARIUM AND *NOTRE CIEL*

French live shows and bilingual French-English live shows at the James S. McDonnell Planetarium have been met with appreciation and positive feedback from attendees. These shows have been able to keep native speaking visitors, students learning a new language, teachers and non-French speaking chaperones engaged and learning about the night sky and the universe around them. Currently, most of the visitors have been younger elementary school aged students from the French immersion school; however, there have also been a few groups of teenage and adult native French speakers on vacation who have appreciated having some content in their L1.

When offering shows in a world language, it is important to only regularly schedule these shows when the presenters who can speak the needed language are available. Another option, which is the route the McDonnell Planetarium took, is to make the show available only through a group reservation for a day when a bilingual staff member is available. If the planetarium is a public institution, it should be well designated that the program will not be in the L1 anywhere a visitor might see the show schedule. All box office team members should also be aware of the language difference so they can make those purchasing tickets aware of the language differences. Finally, it is good to also announce at the beginning of the show that it will be presented in an L2 so that anyone who may have misunderstood has time to exchange their tickets for ones to a show they will better comprehend.

While many live show presenters present without a script and create their shows as they go based on a show's main ideas and audience feedback, as is done at the McDonnell Planetarium, in this instance it would be best practice for a presenter to prepare a script in advance. While this does not mandate the presenter to use the script in real time, it will force a potentially non-native speaker to think through what they want to say and how they want to say it so that they can model proper speech in the L2 for students. Also, as most world language instruction does not include a science unit or a large amount of astronomy vocabulary (most L2 instruction goes as far as giving the vocabulary for the Earth, Sun, Moon, planets, stars and maybe galaxy), the presenter may find they need to research some vocabulary for themselves in advance. Having a script prepared, or at least an outline with key vocabulary, will help a presenter feel more prepared when the time comes to work with visitors in the L2 under the dome.

As mentioned earlier in the paper, talking with the teacher prior to the visit can help ensure that students get as much out of their visit as possible. The first group to attend *Notre Ciel* was comprised of first grade students from a Saint Louis Language Immersion School (SLLIS) who had been speaking French for a year and students new to the school who did not know a lot of French. After talking to the teacher, a communicative show was created to accommodate the young learners at their varying levels. The feedback from the show was positive from the teacher, the students who shouted out answers in French and English, and even the parent chaperones who were surprised to find they understood a lot of the show even though it was completely in French.

It can be difficult getting the word out to teachers about the shows, and even within the same immersion school, teachers may or may not know that a trip to the planetarium is an option. Reaching out to schools and world language teachers personally has seemed to work best. Other means of communication can include e-Blasts or email newsletters, a small description in a program book, listings on the organization's website, and asking reservation personnel to offer the show to those who are booking a visit. It should be noted though, that one should not assume that these later methods are a guaranteed way to capture groups; they do not appear to yield the same results. By speaking to a teacher or the principal personally, they learn of the presenter's interest in working with them and together they can plan a way to move forward with a field trip.

A recent example as to how personal communication can make a difference involved the SLLIS. The French School, Spanish School and Chinese School all fall under the umbrella of SLLIS. A teacher who had brought her students in the spring of 2017 for *Notre Ciel* wound up with a mix of French and Chinese school students in her class during the 2017-2018 school year and felt she could not bring them as only half the students would understand the show in French. Before being able to discuss what could be worked out, they used their fieldtrip funds for the class to go somewhere else. A different teacher from the French School though, paired up with a teacher from the Chinese School to have enough students to bring to the Planetarium.

After a chat with the teachers prior to the start of their visit, it was decided that bilingual instruction would be helpful, and in the end, students thoroughly enjoyed a bilingual French-English show. The teachers were grateful that at least half the students could still be engaged in their L2, and the other students could still understand and participate in their L1. Students were engaged and responsive in both French and English, and the students from the French School were able to briefly converse about beginning concepts regarding stars and their temperatures, and the planets in French after the presentation. Being flexible allowed the students to benefit from the experience as much as possible, and the teachers are now discussing a French School field trip for the next school year.

CONCLUSION

Live French planetarium shows have been met with positive feedback at the James S. McDonnell Planetarium at the Saint Louis Science Center. The introduction of live world language planetarium shows has opened a new opportunity for world language classes, international visitors and the planetarium itself. It is the chance to introduce a new group to other cultures. It is also an occasion to create partnerships with new teachers and schools to introduce meaningful and communicative world language learning in a practical setting. By offering a live world language option, a planetarium is able to welcome a new audience to learn about and find a love of the universe.

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to Amy Neuberger, Esq., Dr. Susan Hildebrandt, Nathan Nass and Gabrielle Coutrot-Hedrick for proofreading, language editing and technical editing.

Many thanks to Pamela Braasch for trusting me with this endeavor and giving the official approval to try something new in the dome with the *Notre Ciel* show and a new audience; even though there was a chance it might not reach anyone from our normal audiences.

Finally, my heartfelt appreciation to Valerie Sacks and John Lakey for the foundation that enabled me to create *Notre Ciel*.

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Paper Title

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BIOGRAPHIES

Milo Grootjen and Mark Spoelstra work at the ARTIS-Planetarium as concept & content manager and audiovisual technician.

ABSTRACT

The ARTIS-Planetarium Amsterdam recently developed a planet-scanner, which makes it possible to easily scan objects and add them to our digital universe. The scanner is very low cost and uses software that scans and launches self-crafted planets instantly (45 seconds) to the dome.

INTRODUCTION

Launching your own planets into the digital universe

The scanner is part of a new "space birthday" program we offer our visitors. After a short introduction about different kinds of planets (rocky, gas, dwarf, exoplanets) the children are challenged to make their own creation. They are given a simple Styrofoam sphere on which their own world can be created. After this workshop we launch the planet together with name and birthday into our digital universe. The scanner instantly scans the object and writes scripts to use in the dome. The scripts give us the possibility to give a special live show. The birthday girl or boy will visit the starry sky of the date of birth, discover their age on other planets while flying through the solar system and ultimately travel to the new exoplanet that they have added to our galaxy. We keep a database of the created planets, which makes it possible to come and visit their worlds at the Planetarium again and again.

ACKNOWLEDGMENTS

- The scanner was made for Planetariums with Sky-Skan digital sky 2 software, but the output can be made applicable for any Planetarium system.
- The software for the scanner is written in Delphi

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New Advertisement Ideas

Levent Gurdemir, UTA Planetarium, The University of Texas at Arlington
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BIOGRAPHY

Levent Gurdemir is the planetarium director at UTA Planetarium of the University of Texas at Arlington. He has 10+ years of experience in running and operating planetariums as well coordinating outreach programs. He has been the president of Southwestern Association of Planetariums (SWAP) since 2016. He also served as president in the same organization between 2010 and 2012. He is currently serving in the IPS's Vision 2020 committee as the head of Goal#5 to provide support and leadership in transitioning to next-generation planetaria design, technologies and content development. Levent Gurdemir has Astronomy and Space Sciences Bachelor's degree and Physics Master degree.

ABSTRACT

The internet has become an unavoidable technology in our lives. Perhaps you have no interest in using search engine tools and social media for your planetarium. However, popular search engines as well as your visitors (people) are already advertising your facility regardless of your interest. The information they have posted may be inaccurate and you should take the control over before someone else does.

INTRODUCTION

You may not be aware but lot of people find your facility through search engines, get directions, find your showtimes, and contact phone numbers. They even read your reviews before they visit your facility. Search engines have lots of inaccurate listings that makes businesses suffer. Social media channels such as Facebook, Twitter, Instagram, Yelp, Snapchat, and many more are also other avenue that people talk and post pictures about your facility. It is important to claim your business name on major social media channels before someone else does and starts posting information for you. Here are some steps to get your internet image started.

I. YOUR WEB SITE

Everything starts with a clear, easy-to-read, responsive website. Here, responsive means your website is being friendly with tablets and smart phones. You need to list your operating hours, showtimes, blackout dates, etc. very clearly as it will likely be picked by search engines and displayed to your visitors.

Every website contains hidden information called tags. Tags are the keywords about the website used by search engines. Search engines use tags to decide whether your website is relevant to the user searching something on the web. Keywords can be something like planetarium, night sky, stargazing, solar system, astronomy, telescope, etc. Properly tagged website is called Search Engine Optimized (SEO). You can test the optimization of your website by running a web search in your local area. Keyword "planetarium" search should bring your planetarium as the first order in the search results.

Your website should also have modern looking and contain pictures from your facility. Pictures that show visitors are most impactful as it will relate the experience. Pictures should be taken with professional camera. Pictures taken with cell phone should not be used on websites.

Moreover, you don't have to have great website development skills to develop a good-looking website. There are lots of tools available out there. If you are hosting your own webserver, you may want to investigate Content Management Systems (CMS) such as WordPress. CMS is a software that offers you templates. You simply select your template and place your pictures and text to the website. If you are not hosting your own webserver, there are other tools available out there. Wix, Weebly is to name a few.

The summary of this section is:

You need a website that is

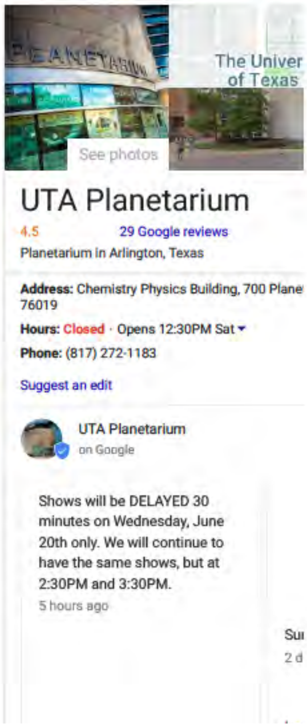
1. Responsive
2. Search Engine Optimized
3. Modern Looking and easy to edit/update

II. SEARCH ENGINE LISTINGS

Search engines (Google for example) automatically pick up businesses' information from websites and publish it publicly. As more users today use smart phones to get information, search engine listing accuracy becomes critical. Search engines may contain wrong information about your location, showtimes, admission price, etc. that may result lot of angry people.

Below is the google listing of UTA Planetarium. It shows pictures of our facility, location and contact information, hours, and reviews. Google even picked a show delay information we posted on our website.

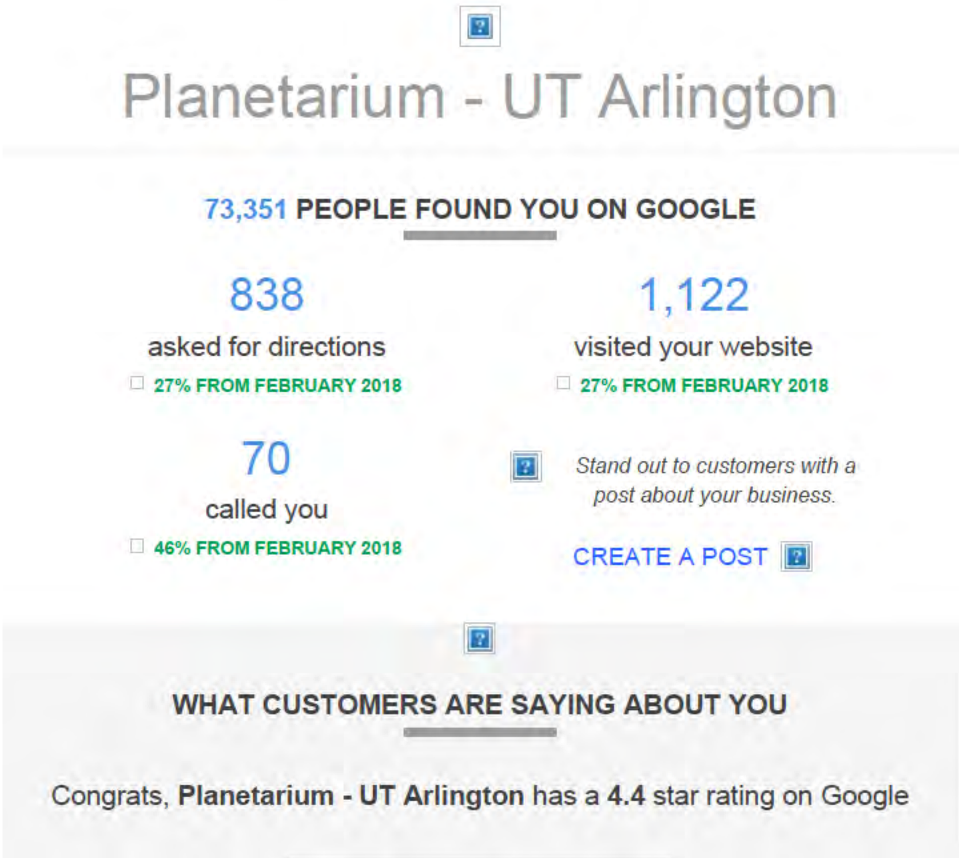
Figure 1 – Google Listing of UTA Planetarium



You probably have Google listing for your facility even though you didn't provide any information. Google picked all the information from your website and created the listing for you and now your visitors can find directions to your facility, your hours and phone number. There may also be reviews from your visitors. That listed is not editable until you claim your business account with Google. There is no cost create Google Business Account to edit your listing. Google will verify your information and give you control of the listing.

Below is the statistics sent by Google the following month after we created our business account with Google. The numbers were shocking.

Figure 2 – Google Statistics



III. SOCIAL MEDIA

If you don't have your social media accounts by your planetarium name, you may want to claim them before someone else does, even if you don't intend to use them. It's all about the name. Your visitors are likely social media users and search for you on the social media to get connected. Internet pirates claims unclaimed business names on the social media due to potential "accidental" draw. When they reach significant subscribers from your visitors, it brings potential value and price tag to the account.

Major social media outlets you may want to claim your business name are:

1. Facebook
2. Twitter
3. Instagram
4. Yelp
5. Snapchat

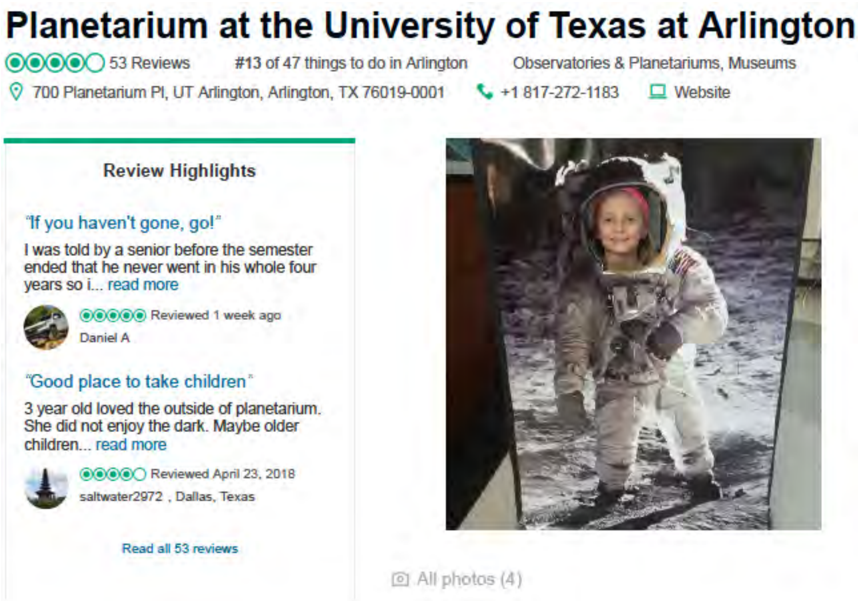
Once you created your facility's account with the social media, accept visitor subscribers and let the number grow. There is significant potential to reach more people using those social media outlets.

IV. INTERNET REVIEWS

Time is valuable and no one wants to waste time by visiting a place that they won't like. A lot of people read at least a few reviews if they are unsure that a planetarium visit is something they want. While there may be hundreds of websites who posts reviews about your facility, I found Google and Trip Advisor used most for planetariums. You cannot delete or edit your reviews, but you can increase the positive review by encouraging your visitors to leave a review. It would certainly not look good if your facility has low stars on Google and Trip Advisor.

Below is the snapshot of the Trip Advisor page about UTA Planetarium. This page wasn't designed or edited by us and we have found it while searching our planetarium on Google.

Figure 3 – UTA Planetarium on Trip Advisor



You may also find significant number of personal blogs talking about your facility. They are likely written by people who visited your facility. It is always good idea to do a quick "Google Search" about your facility to find out what people on the internet is talking about you.

V. GOOGLE ANALYTICS

Google Analytics is a free service of Google that allows to monitor traffic to your website. It shows number of people visited your website, geographical location of the visitors, which pages they visited most, and when they visited. Google Analytics also contain information such as how long time your visitors spend on each page of your website.

Google Analytics information may be instrumental to develop a new marketing strategy and track impact of advertisement.

Google Analytics require a piece of code to be added to your website.

Dome Content: Live Shows

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BIOGRAPHY

Johan Gysenbergs is team leader Operations at the experimenta in Heilbronn-Germany and IPS fellow.

ABSTRACT

Extending a classical planetarium setting into full stage scenery -and vice versa- provides a lot of extra opportunities presenting live shows.

INTRODUCTION

The newly to be build Science Dome in Heilbronn, Germany will exist of a revolving platform in which the audience will be rotated from a stage into full dome modus.

I. DILEMMA

Many unidirectional seated planetariums hold a small area for stage performances and often are limited in live performances due to space limitations. It is even a bigger problem with omnidirectional seated planetariums.
Historical there was not much need for extra performances under a dome. An opto-mechanical projector provided all there is to a star show.

Planetariums today have much more to offer due to evolving culture attitude and learning processes, progressing projection techniques and competition from entertainment venues.

There is a constant need to spread ones wings to please the flow of visitors and keep the integrity of your planetarium.
This will reflect the use of its available real-estate inside each planetarium.

A dilemma pops up if planetariums want to deal with a multi-purpose environment for their theater without changing their visitors from room to room. What if a theater could provide a stage and a full dome in one go for instance?

To date a few efforts try to deal with this dilemma. Moving domes or half sized domes with mechanics that can lower or higher a dome over its audience in order to make way for a stage exist. Seats can be assigned beyond the periphery of the dome itself for stage performances.

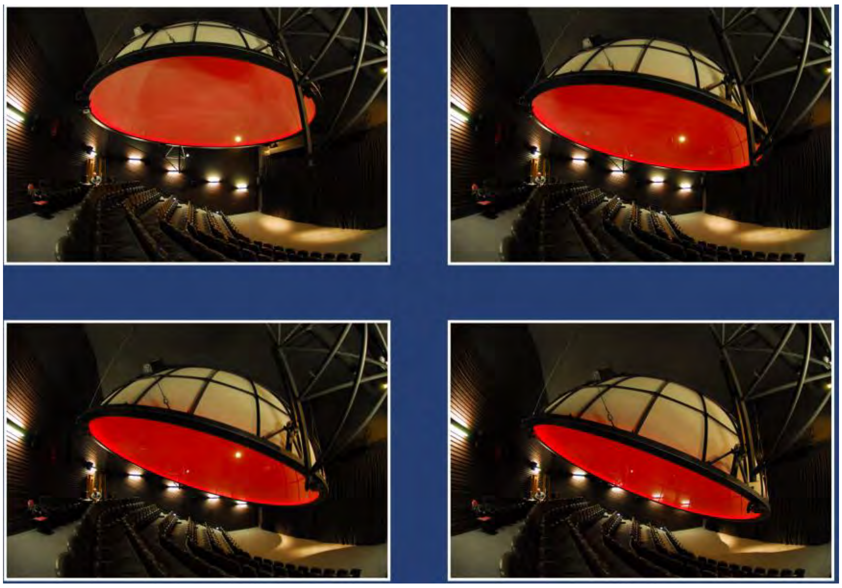

Figure 1 – dome movement Mt Cook New Zealand

Figure 2 – QM2 Dome Theater

Another solution is to completely remove the seating within the planetarium to make room for any other kind of exploit. It is often used for catering and rental events but could be used for simple walk troughs, camping or artistic performances.

Figure 3 – Dome use Space Place Wellington ©

On the other hand more and more designated class-room planetariums are used within the facilities of high schools and universities. The planetarium has one specific teaching purpose and limits itself by default from wide-ranging activities.

II. THE EXPERIMENTA APPROACH

Experimenta's Science Dome in Heilbronn-Germany is capable of rotating its whole audience into dome or stage modus whatever is preferred for its shows.

To change between dome- and stage viewing modes, the entire 150-seat audience platform can be rotated 180 degrees. The Science Dome is equipped with 8K dome projection, 3D audio, lighting and recording systems, digital planetarium image generators, an opto-mechanical star projector, a laser system, projection water screen, additional cinema projection screens, complete stage technology, can be linked to the rooftop observatory and is prepared for high voltage and chemical experiments.

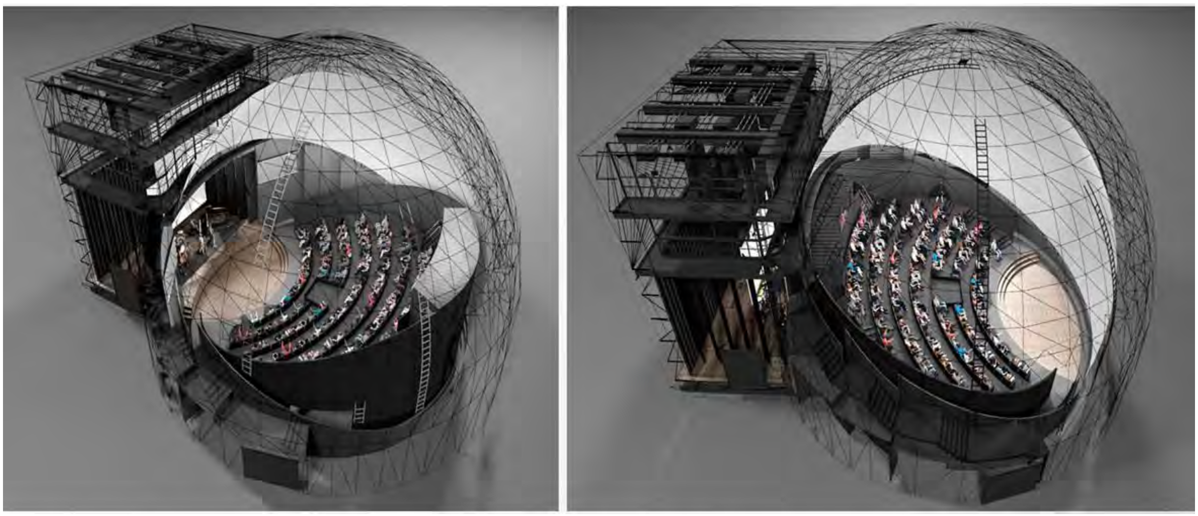

Figure 4 – experimenta Stage – Dome modus

The Science Dome will be operated continuously on a dense schedule, with content from all STEAM and related fields and formats ranging from full-dome movies, planetarium and live experimental shows to concerts, theater, talks, music and laser shows. Shows are developed for different age groups, covering all ages and targeted to also attract youths and young adults.

Finding the optimal way of using the combination of dome, stage and ample multimedia technology poses challenges, and offers opportunities to gain insights useful for the world-wide planetarium landscape as it develops towards digital, multi-purpose multimedia domes.

The prospects are obvious: a whole orchestra now can be part of the performance and larger theater spectacles can add to the dome experience. The rotation itself now becomes part of a show element.

Figure 5 – artist impression of stage under the dome

This approach does not make it easier for productions. The regular approach of pushing a full dome show button ends here. Production needs carefully thought over in use of its available space.
Most of our regular shows will start with a live presence on stage to introduce a subject and turn the audience into a full dome presentation.

In a more complicated scenery, a stage live act can be combined with full dome modus and even return to a stage story.
For that matter presenters are casted with theater and science skills which are a challenge on its own.

Even in a full-dome mode a smaller stage upfront of nearly 100m² is available for other interactive and live use. The stage performance can be continued into full-dome modus as well.
It all needs to be planned and scripted accordingly since there are safety issues involved. Sensors fi. prevent visitors from entering the stage during High Voltage or laser shows.

But the real estate is there to comply with numerous of visitor's educational and entertainment wishes.

It is up to the Science Dome team to achieve them.

Virtual and Mixed Reality and the Science Dome

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BIOGRAPHIES

Ralph Heinsohn is Creative Director and Head of production for the Science Dome Content at the experimenta in Heilbronn-Germany and IPS fellow. Besides, he is curator of the 360° cinema of the Nordic Film Days Lübeck / Germany.

ABSTRACT

Digital domes increasingly interact between Dome content (Group VR experience) and Virtual Reality content created for head-mounted displays (Individual VR experience). How does that affect our dome content conception?

INTRODUCTION

The dynamic trend of augmented and virtual reality bears many challenges and opportunities, both technology and content wise. Digital dome projection has its own characteristics, but yet a digital dome theatre experience shares the power and possibilities that immersive media offer.
So far, dome and HMD-based experiences probably haven't been considered as twins by planetarium visitors or Virtual Reality Headset users, as both technologies were targeting different markets.
But not only due to the development of tools, that are being used in both worlds, such as software and camera systems, the question of connected conceptual strategies as well as an overall conversion of both technical devices comes up.
With a new digital dome theatre being built up from scratch, the Experimenta is researching for opportunities and solutions.

I. IMMERSIVE MEDIA IN THE EXPERIMENTA

I.1 The Science Dome

The science dome is an exceptional high-tech experience space with rotatable auditorium, theater stage with complete stage technology and stage live events, additional cinema projection screens, show laser technology, fog machines, projection water screen (water curtain), a 3D audio system, fulldome video projection (8K, 60fps, 3D), an opto-mechanical star projector and digital planetarium system. Visitors can lean back in comfort in the flexible seats (150). The Science Dome will be operated with content from all STEAM and related fields and formats ranging from full-dome movies (both of own production and licensed shows), planetarium and live experimental shows to concerts, theater, talks, music and laser shows. Shows are developed for different age groups, covering all ages and targeted to also attract youths and young adults. Within the content production studio, there is also a small dome with 2 diameter for previewing dome material.

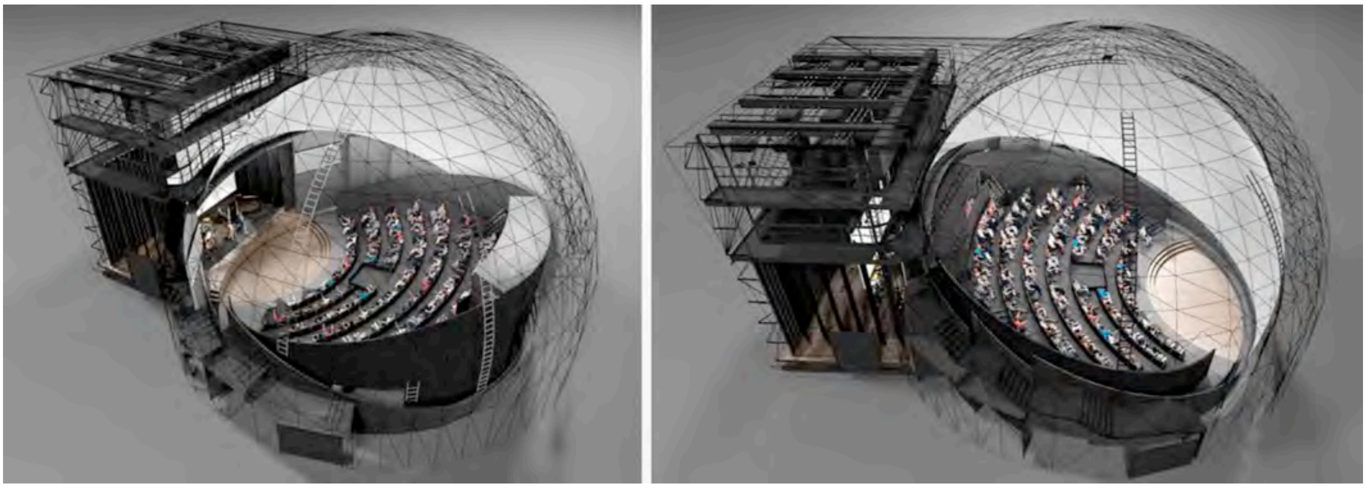

Figure 1 – The Science Dome

I.2 HMD-based Immersive Media in the Experimenta

VR Headsets will be used in various exhibits in the exhibition areas, both as standalone experiences, as well as a complimenting device for complex exhibits such as a crash test car. Visitors such as school groups will be able to use Headsets in the laboratories, for learning, entertainment and explorational research purposes. But also within the content production team, VR headsets are used for production previewing purposes.

II. FULLDOME SHOW PRODUCTION AT EXPERIMENTA

II.1 Fulldome show production

The Science Dome has its own production team with in-house 2D- and 3D-artists as well project management and technical direction and cooperates with external freelancers and studios, in particular for specialized spatial audio production. We are using 3D-CGI-Software, 360° camera rigs and standard video editing tools to create pre-rendered content. We run and maintain our proper render farm and use particularly developed production tools.

II.2 Previewing Fulldome content

The Science Dome will be open nearly 24/7 with operation times during the entire day. To test our rendered content, we created a proper realtime tool, driven on HTC Vive / steam, entitled „DomeVRplayer“ to simulate the Science Dome virtually with all technical features mentioned above. Also, we are lending this system to external coproduction partners that produce fulldome material externally and who are located and working remote. Besides, there is also a small dome with 2 meter diameter for previewing dome material – and we are cooperating with Planetariums in our proximity, such as the Planetarium Mannheim and the Planetarium Stuttgart.

Figure 2 – Virtual Science Dome

II.3 VR-tools in show production

Currently we are testing VR content creation tools (i. e. 3D-modelling) to create sequences for our Fulldome shows. These sequences will be rendered out as equirectangular images and post processed by 360° video editing tools.

Figure 3 – VR modeling tools (i. e. Tilt Brush)

III. REALTIME, INTERACTIVE 3D CONTENT: GROUP-VR

III.1 VR-tools for live shows

We are also dedicating time to R&D of using realtime 3D content for straight live output into our dome – avoiding rendering times and to create opportunities for realtime live interaction with the visitors..

Figure 4 – 3d assets as live 360 video image generator

III.2 interaction inside / outside the Science Dome

Furthermore, R&D aims at developing content that can be displayed simultaneously inside the dome as well as outside the dome on VR Headsets, video panels at various locations inside the entire Experimenta – or probably even remote.

Figure 5 – in front of the science dome entrance

III.3 proof of concept

First prototypes have been developed for and tested within a mobile dome on the Film festival „Nordic Film Days Lübeck“ / Germany, which had been initiated and curated by Ralph Heinsohn. Within that approach, a VR-artist was acting on stage inside his individual VR. The 360°-video signal was connected to the dome so that the audience was experiencing the artists virtual reality environment and interactions simultaneously inside the dome.

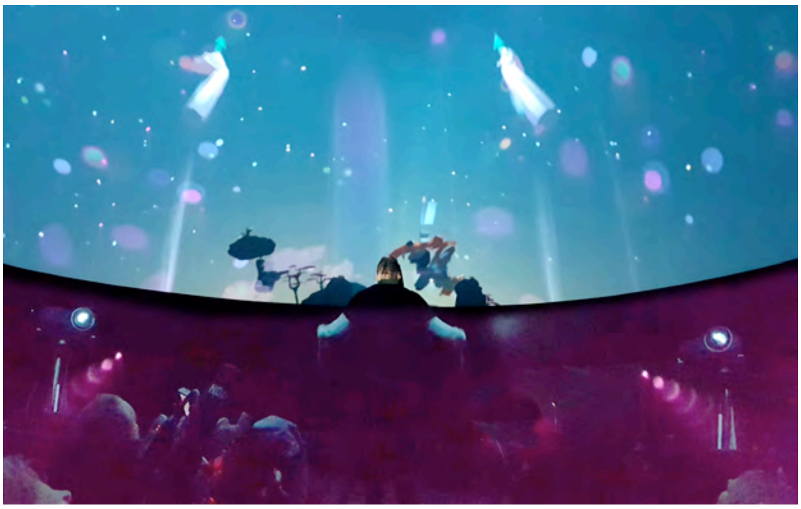

Figure 6 – sharing individual VR experience with a group in a dome at Nordic Film Days Lübeck

Experience over description

"Dimensions – Once Upon Our Reality"

A concept for an educational art and music show

Dipl.-Des. Rocco Helmchen (visual artist), Johannes Kraas, M.A. (composer)
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BIOGRAPHIES

Rocco Helmchen:
Rocco Helmchen is a freelance visual artist and fulldome filmmaker living and working in Germany. Together with composer and sound designer Johannes Kraas he produced several full-feature planetarium shows and realized dozens of other dome related film projects.

Johannes Kraas:
Johannes Kraas graduated as Master of Music from the conservatory in Münster, Germany in 2009 and is since then working as an freelance media artist, sound designer, and composer.
Together with media artist Rocco Helmchen he realized various fulldome projects, such as „tempus.ruhr", „Chaos and Order" and „Dimensions".

ABSTRACT

What is "reality"? Is it just the interaction of time, space, particles and forces? A hallucination created by billions of neurons in our body? Many of the big questions are since impossible to answer, yet they fire up our curiosity to know more.

The theoretician Ronald Jones's "theory of unknowability" gives experience the preference over description in order to avoid using "old" terms which fail to adequately communicate the new.

Based on this approach we tried to develop an additional educational show format that - even if it doesn't provide all the answers - inspires love and fascination for science, discovery and the mystery of our existence.

INTRODUCTION

Planetarium programs are strictly divided into certain genres. There are astronomy shows, children shows, art-projects, music shows, radio plays, concerts and many more. Every new production has to fit into one of these boxes. We want to brake open these boxes and try to fuse different approaches and styles of shows together in the search for a new show format located in the crossover space of art and science. As we ourselves aren't scientists but artists inspired and driven by scientific discoveries we set out to use our abilities to share this deep fascination with an audience in a planetarium. The following is intended to give a brief conceptual insight in the process of making „Dimensions – Once upon our reality"

I. WAYS TO DIMENSIONS

I.1. Experiences with Chaos and Order

Our first attempt to create an „edu-tainment" Show was „Chaos and Order - A mathematic symphony". We primarily tried to create a piece of entertainment, but at the same time we wanted to put a seemingly dry subject like mathematics in a colorful spotlight to make it appealing to a wider audience. The reactions to this new approach to education was highly positive. Learning from and building on these experiences we tried to further develop that format. We also looked at other more traditional planetarium shows and how they mix the three main ingredients, namely visuals, description (mostly in the form of narration) and music.
We decided to the adjust the ratio in a way that the main focus would lie on the music and the visuals to give the audience more space and time to think and feel. Instead of first having a topic for a new show we decided that we would like to further develop the format we had already established. So we asked ourselves what story, or theme would benefit from being told in this kind of show-format? The question of the nature of our reality seemed to be a great fit for a different approach to a planetarium show. The questions if parallel universes exist, if we exist in infinite variations, what really exists after all. All of this is still in big parts unknown, but nevertheless fascinating.

I.2. Agnosiology

The British artist and theoretician Ronald Jones has proposed the concept of agnosiology or the „theory of unknowability“. This gives experiences that are free from terminology the preference over descriptions using „old“ terms. These established terms would fail to adequately communicate the new and the unknown. This seemed very fitting for the subject and the story of Dimensions.

Using the immersive space of the planetarium dome we are able to translate scientific insights and problems into experiences that follow an unconventional logic. This approach is particularly well suited to convey ideas and concepts for which the audience lacks an appropriate language in their everyday life. What hopefully sticks with audiences is a feeling that there are unexplored worlds and realms in us, and all around us, that influence us in a maybe more profound way then what we already know and understand.

II. DIMENSIONS – ONCE UPON OUR REALITY

II.1. Can a „music show“ in a planetarium context be in any way educational?

We think it can, if we push the boundaries of what is regarded as "education" beyond the description and teaching of facts. Even if the latter should always be the planetariums main purpose, there can be additional approaches of creating formats that inspire love and fascination for science, discovery and the mystery of our existence. Sound in general is the first and most direct form of understanding the world. Music is received directly by the inter-brain, the emotional receptor, the instinct-based part of the brain. Music can not only help to increase the attention of the viewer, it also communicates with him on a subconscious level and makes him receive additional information. In many of the more traditional planetarium shows we looked at, we realized that the text ratio is quite high compared to music ratio.

We are convinced that music can work as an important messenger, that it can help to transfer information by creating emotions towards something that is seen on the screen. That is after all how every movie works. Music creates emotions, and everything that creates an emotional reaction from the viewer makes him participate and follow more actively. When music and visuals go well together, when they become „one“, the viewer is transported right into the show, instead of just observing it. Especially in an immersive environment like a planetarium!

II.2. Narration

After learning from the feedback we got from Chaos and Order, it seemed that it was one thing to put the audience in an immersive and fascinating world of math, where they can enjoy the beauty of formulas, fractals and numbers, but it was a whole different thing to explain math to them. Even that wasn’t what we planned to do in the first place, at least there was the wish to know more about maths from many viewers, which was a great thing, since we accomplished our mission to create interest in a rather dry school subject. Since we are no scientists ourselves we decided we’d rather not try to explain in detail Einsteins theory of relativity, string theory and the concept behind parallel universes. That would have been destined to fail. But nevertheless we felt that we would like to at least guide the audience a little by introductions to all of the four acts of the show. We tried to open the door to complex worlds by asking questions, providing an understandable dose of information and give everyone some „food for thought“ to hang on to while diving into the unknown.

To ensure the necessary scientific accuracy we had help from Prof. Dr. Susanne Huettemeister, the director of the Zeiss-Planetarium Bochum, Germany who supported the writing process and was a great mentor when it comes to science and physics.

We also put great effort in finding the right narrator. The voice had to fulfill the requirement to evoke a mystic fascination on the one, but yet to sound factual and grounded on the other hand. In other words, it had to have the right mixture of entertainment and education, just like the show itself.

II.3. Visualizing the unknown

With the decision to use narration and explanation only in a very small dose there was a big challenge to not loose the audiences attention in seemingly arbitrary visuals. The show needed some kind of structure and a dramaturgy which would lead the audiences attention from theme to theme. This was achieved but dividing the show into 4 acts plus a prologue and an epilogue. The 4 acts include the topics space-time, the quantum world, the „inner“ and „outer“ universe and the idea of a multiverse.

The visuals are varying between science visualizations, artistic interpretation of scientific concepts and real time sequences filmed in science institutions that actually explore the nature of reality.

II.3.1. Visualization

Generative abstract visuals are particularly well suited to visualize the unknown. As they are designed to generate images which resemble the natural world around us using mathematical algorithms, they can also be used to design and render things we don‘t have a visual concept for yet. Every visual world these digital processes generate could be regarded as a real place. The great art historian Kirk Varnedoe once said about abstract art: „It reflects the urge to push towards the limit, to colonize the borderland around the openings to nothingness, where the land has not yet been settled, where the new can emerge.“ It is the show’s purpose to take the audience to exact these unsettled places.

This also touches a point the show is making in the epilogue that the only language capable of describing the new insights into the nature of reality is the universal language of mathematics and that these are often explored using computer algorithms.

II.3.2. Real time 360° video

One of the narration’s purposes is to bring the audience back to the themes and keep them from becoming confused by the journey through all the abstract audiovisual worlds. The same goes for the 360° video sequences, filmed in actual science labs in which the discoveries are made that might one day answer the questions the show deals with. Accompanied by dissolving scenes from every day life these sequences tie the audience back into the real world as the starting point for their journey.

III. CLOSING REMARKS

Instead of having separate elements of narration, an underscoring turned-down carped of music and explicit scientific visuals, we rearranged the elements in a way we thought them to be more related to each other. In a way it follows the concept of Visual Music, where music reacts directly to the visuals and vice versa. What you see clicks with what you hear, and thus creates a connection from the rational to the emotional parts of the brain, what again leads to a deeper immersion, if not even to a deeper learning experience.

All of this is just based on what we think and have experienced. Over the years we have seen lots and lots of planetarium programs. This is in no way meant to replace the existing and established classic forms of planetarium shows, but we think that this could be an efficient additional way to enrich any planetariums repertoire and to educate and entertain at the same time.

Our goal is to develop concepts and shows that are not only for special "arts under the dome" events or fulldome festivals and showcases, but could function as an element in a day to day planetarium schedule.

ACKNOWLEDGMENTS

We would like to acknowledge the help and support from the Zeiss-Planetarium Bochum for this production, especially Prof. Dr. Susanne Huettemeister, Tobias Wiethoff, Meike Weissner and Klaus-Dieter Unger.

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Planetary Playhouse: Stories from Our Solar System

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BIOGRAPHIES

Mike Hennessy, Buhl Planetarium Manager- planetarium educator, scriptwriter, showrunner

Charissa Sedor, Buhl Planetarium Producer- planetarium educator, media producer, systems coordinator

ABSTRACT

Just as space probes have transformed astronomy, planetariums have the power to transform the future by providing memorable learning experiences for our visitors. Carnegie Science Center's Buhl Planetarium is endeavoring to shape the future through new presenter-led shows that combine the breathtaking visuals of the full-dome planetarium environment with the energy, impact, and engagement of live theatrics and storytelling. Two new shows, *Expedition: Solar System* and *Mars Madness*, reflect our commitment to combine live theater and planetarium visuals to delight audiences, inspire future scientists, and promote scientific literacy.

INTRODUCTION

"If you want to make an apple pie from scratch, you must first invent the universe." Carl Sagan famously explained that the elements in an apple pie were formed inside ancient stars--"baked" in cosmic furnaces. This description of a long journey from raw materials to finished product is an apt metaphor for the challenges faced by planetarium educators. To "bake" a new show from scratch, planetariums face several challenges: affordability, staying current with headline news in space exploration, and meeting the needs of our visitors. The recipe for success can be found in a combination of live theatrics and planetarium visuals—"the best of both worlds." Through live theatrics and storytelling, the planetarium becomes a cosmic stage in which guests are inspired be actors in a universe of possibility.

Carnegie Science Center's Buhl Planetarium has developed two new storied journeys—*Expedition: Solar System* and *Mars Madness*—presented as live theatric programs which unfold against the cosmic canvas of the planetarium. These programs blend immersive planetarium visuals with audience participation, storytelling, and props. Our goal is to inspire audience members who participate in these shows, to participate in the real story of science—whether as future scientists, scientifically engaged citizens, or astronomy enthusiasts. These programs were developed to support science comprehension and galvanize interest in Earth and space science, as we face the challenges of global conservation and the promise of interplanetary exploration.

I. SECTION 1: EXPEDITION SOLAR SYSTEM

I.1 Show Description

Expedition: Solar System was developed for primary school student and family audiences. In *Expedition: Solar System,* students are led on a mission by a presenter playing the role of "Captain." The Captain banters with Quasi the Robot, a loveable animatronic sidekick, voiced live by a different presenter backstage. Quasi the Robot is a social-emotional animatronic, whose eyes and antennae move and change colors to signal his mood and provide an emotional connection with the audience. Our adventure through the Solar System is accomplished through flight in Sky-Skan's Digital Sky, with a few punctuations of short full dome animation, and orchestral music inspired by famous science fiction movies. Visitors soar over the canyons and mountains of Mars, the rings of Saturn, and the heart of Pluto. As students fly to other worlds to investigate, Quasi the Robot patches through to his robot buddies—the fleet of NASA satellites exploring the Solar System. Quasi serves as a robot ambassador, explaining and celebrating the accomplishments of missions such as Akatsuki, Juno, Cassini, and New

Horizons. Students learn about the role of robots in expanding our knowledge beyond our senses. After this introduction to comparative planetology, our mission returns to Earth, which Quasi declares perfect as our home planet, "our place in space."

Figure 1 – Quasi the Robot

I.2 Pre-Show

Expedition Solar System often begins with a light-hearted, interactive preshow, in which student volunteers come to the front playing space of our unidirectional planetarium and proudly hold up beachballs representing the Solar System. A set of beachballs which resemble the planets are used as a familiar starting point, so the audience can see the planets in sequence and their major colors and features. Then, using the Earth beachball as a reference, the other planet beachballs are switched out for scale objects, from tennis balls to a giant inflatable representing Jupiter. This pre-show helps to frame the adventure. It can also stand alone as a classroom or exhibit gallery activity.

Figure 2 – Beachball Planets with Quasi the Robot

Figure 3—Scale Inflatables Representing Planets

II. SECTION II: MARS MADNESS

Mars Madness was developed for students in fourth grade through eighth grade, as well as public audiences. In *Mars Madness,* audiences join in the fun of creating radio sound effects as the planetarium is transformed into the CBS Mercury Theater on the Air, circa 1938. Costumed presenters tell the story of Orson Welles' radio dramatization of H.G. Wells' *The War of the Worlds.* In the program, the presenter engages the audience with slinkies, thunder effects, a Theremin, and the simple creaking sound of a lid unscrewed from a glass jar--pivotal to the story. With a flashlight, finger snaps and foot stomping, the presenter leads the audience in creating a "dark and stormy night"." Then, the sonorous tones of Orson Welles and breathtaking planetarium visuals take over. The presenter continues to narrate, with snippets of the 1939 radio broadcast included. *Mars Madness* discusses our fascination with Mars in science and science fiction. The program considers the state of astronomy in the public consciousness in 1938, and the uncertainties around Mars which contributed to the broadcast's success. *The War of the Worlds* is used as a springboard to discussing modern research into astrobiology, exoplanet, and ultimately robotic exploration of Mars. Finally, the Earthlings become the aliens! Students learn how robots are paving the way for Earthlings to one day "invade" Mars. The audience joins the Mars Rover *Curiosity* in the search liquid water and the search for evidence of ancient life. A full dome animated finale, complete with 1930's jazz band music, celebrates our exploration of the Red Planet.

Figure 1 – Mars Madness Title Card

Figure 2– Mars Madness Presenters with Theremin

ACKNOWLEDGMENT

N/A

REFERENCES

N/A

So you want to build a planetarium?

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BIOGRAPHIES

Torvald Hessel graduated with a Masters in Astrophysics from the University in Amsterdam, The Netherlands. During this time, he worked at the Artis Planetarium as a presenter and educator. In 1999 Hessel emigrated to the United States, and in 2003 founded the "Austin Planetarium" a not for profit in Austin Texas, which had as goal to establish Austin's first Planetarium. After coming close to success several times, finally in March 2015 the organization opened a museum facility in a leased building of 3000 sq. m. and changed its name to the "Texas Museum of Science & Technology" (TXMOST). In February 2018, Hessel resigned from the museum. The museum was closed six weeks later.

Currently Hessel is looking for new opportunities, hopefully in the same field of informal science education.

ABSTRACT

The opening exhibit was BODY WORLDS, and in November of the same year a 10-meter planetarium dome was added. The museum attracted 60,000 visitors in its first year. Over the three years since opening, the museum was slowly upgraded with each exhibit swap, and after three years the museum reached capacity, at which point the museum board decided to close down the museum.

So, what happened? Why did this project fail? Could this have been prevented? In this talk we will discuss these issues, and hopefully can offer useful "lessons learned" to the audience.

INTRODUCTION

Introduction of speaker and bio

I. SECTION 1

Brief overview of the TXMOST project and timeline

II. SECTION II

II.1 Analysis of what went wrong and why the board closed the museum

II.2 Discussion of what could/should have been done differently, possibly preventing the museum closure

II.3 Future dreams?

ACKNOWLEDGMENTS

NA

REFERENCES

NA

Best practices
How to get the most out of your live shows

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BIOGRAPHIES

Marc Horat is an Astrophysicist and Director of the Lucerne Planetarium at the Swiss Museum of Transport since 2014. He has a rich experience concerning live and preproduced shows and he is the producer of the first freely available planetarium show in 8K "Out There" and a Digistar power user.

ABSTRACT

Live presentations are the most challenging shows you can do under the dome. A presenter must bring a wide range of skills to engage the audience. What can we, as dome managers, do for them so that they can perform at their full potential? I will cover some best practices gained from my own experiences running the Swiss Museum of Transport Planetarium in Lucerne, Switzerland. Topics will be recruitment of suitable staff, practical and technological insights as well as methods and communication strategies.

INTRODUCTION

With the advent and subsequent evolution of digital planetarium technology to this day one particular type of show from classic projector-driven planetaria had a comeback: Interactive live shows. For digital only systems the source of the dome content now is one single machine – a situation we had before only at the beginning of the modern planetarium where this was done by only using star projectors until the advent of slide projectors to supplement the night sky.
When you ask planetarians what doing a live show means to them you'll get many different interpretations and opinions of the term "live". Some will think of live commentary to a prerecorded show, some will be using the live capabilities of their systems to do a show to a prerecorded narration. Therefore, one has to nail down the term "live presentation" before the requirements for the staff who will execute such shows are defined.
Introducing new people to an existing team is always challenging, especially if the field of work is something as unique as a planetarium where most new members don't have any previous experience in. I will present some best practices on how to deal with these circumstances and build upon my own experiences establishing a new live presentation format at the Swiss Museum of Transport Planetarium in Lucerne, Switzerland and the challenges encountered during this process.

I. WHAT IS LIVE?

I.1 What kind of shows are presented in a typical planetarium?

Even with only a star projector available, there are many possible ways to do a show for your audience: Either the narration track is prerecorded (playback) and the presenter executed the movements of the projector or the presenter also simultaneously commented on the things he or she showed on the dome, which was very challenging. With a digital planetarium system or a hybrid one there are many more possible ways on how to present content to the audience. Now the dome content also can be a fulldome movie. Especially in large planetaria a typical show often consists of a such a preproduced movie with a prerecorded narration track (represented by the symbols on the far left in Fig. 1). This is commonly supplemented by a live segment explaining the current night sky or an additional presentation by the staff for further clarification of or introduction to the topic shown in the movie. For simplicity those mixed content shows are ignored in the following discussion. A "show" can be considered being just one element of a longer presentation. But of course, instead of played back commentary presenters also can comment on the movie contents themselves, either by sticking to a fixed script or by freely adjusting their commentary so that it matches their current audience (second column of symbols in Fig. 1). Within newer installations, the fulldome movie can be replaced by the real time rendering capabilities of a digital system, either by a fixed script or manual control by the presenter and again with prerecorded or presenter narration (last two columns of symbols in Fig. 1 respectively).

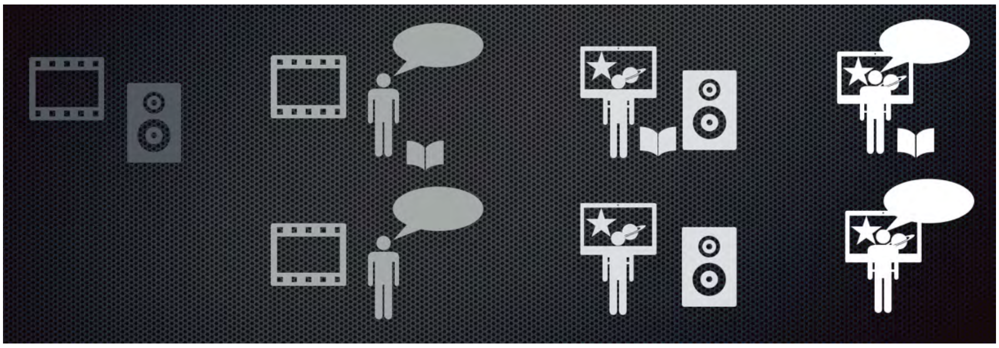

Figure 1 – Different forms of presentation in a digital planetarium. Is the content in the dome and the narration preproduced, scripted or done by the staff?

I.2 Coining the term "live"

The most challenging of these different kinds of presentations is the one in which the presenter manually controls the real time system and narrates the show simultaneously (symbols on the right in Fig. 1). An additional level of difficulty can be added when he or she adjusts the content of the show on the spot to suit his or her audience best. This can happen on the spot by interacting directly with the visitors or by simply presenting content that is proven to work well with a certain age group. This is of course being the same type of presentations like the ones using only a star projector back in the day. But now the presenter is not just the guide for the current night sky but for the Universe as a whole with basically endless possibilities of what to show in the dome. For me this last type of show is the only one that truly deserves the label LIVE. One can see such presentations as a stage performance with no fixed script and a lot of improvisation. If done right this will be the most engaging type of show for your audience under the dome, especially when live interaction is involved. People usually do not expect something like this to be possible and are extremely surprised when they are involved designing a show on the spot. This also changes the way the audience sees the presenter: Instead of a mere button pusher that hides behind his or her desk the perception switches to being more like a kind of performer that does his or her best to deliver a great and unique show. The term live essentially signals that the show the audience is about to see won't be repeatable and that this truly is a one-time experience.

II. EXPERIENCES AND CHALLENGES IN ESTABLISHING A LIVE SHOW FORMAT

II.1 Situation in Lucerne

At the end of 2013 the 18-meter planetarium system in Lucerne was upgraded. Until then, a Zeiss Mark Vs was installed along with a DigitalSky 2 by SkySkan Inc. since 2001. This was replaced by a full digital system from Evans & Sutherland, a Digistar 5 “8K”. The optomechanical projector was removed, so all the content on the dome now originated from a single source – a situation we had never before as there always where slide projectors present beside the Zeiss since the opening in 1969. I took charge of the facility in July 2014 and the team was still the same like before the upgrade. The transition went smoothly and a number of shows were presented each day consisting of a preproduced movie and a short live segment at the end which focused on the current night sky and a short trip to space afterwards. I planned to introduce an all-live show which occupies a whole block (45min). But the team composition was about to change rapidly due to several retirements in the very near future. Within a year I had to replace more than half of the existing presenter staff of six (see Fig. 2). So, one of the first challenges was to think about the necessary skills my staff would need so they would be able to perform the live shows I had in mind. On one hand these changes were of course difficult to handle as much knowledge concerning presenting in the dome was about to be lost but on the other hand this allowed me rebuild a good portion of the team with people suitable to work on an all-digital system.

Figure 2 – Evolution of the presenter team composition in Lucerne after the upgrade to digital. Dark violet: Team members that were already present before the upgrade. Violet: Team members replacing others. Green: Additional new team member

II.2 Necessary skillset of a presenter

So, what are the skills people should bring along to get the most out of live shows? The job is extremely challenging. Simultaneously steering a complex digital system and narrate in a coherent and understandable way requires a lot of skill. I set priorities in a maybe surprising order. First of all, a presenter has to be rock solid in his or her interaction with the planetarium system and must under no circumstances be helpless in what to do next if something goes awry for technical reasons. Also he or she has to be curious and explorative for new content in the system and willing to do a lot of trial and error. Second, one has to be highly skilled interacting with the audience and in explaining things to them. Last but not least, good knowledge in astronomy is helpful for starting the position. But what’s even more important is fascination and curiosity for this topic. Knowledge in astronomy can and will be built over time while the necessary technical and didactical skills are a prerequisite in my opinion.

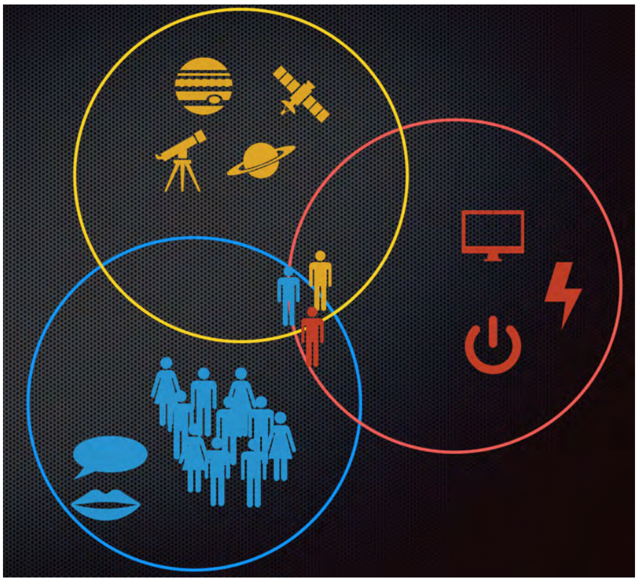

Figure 3 – The skillset of different presenters. Some might be better in the technical stuff (red), some have a greater knowledge in astronomy (yellow) and others are talented show narrators.

II.3 Training of new team members

Of course, you probably won't be able to find a single person which brings along all of those skills. In reality every single presenter or candidate will have his or her own skillset where some of them are well developed and some might not (see Fig. 3). One can use this fact to your advantage during the training of new employees. I successfully established a learning-by-doing concept for new team members: Trainees will join one of the presenters during their daily work and directly learn from them. As the tutor changes from day to day new employees will benefit from the different skills and experience a variety of how things can be done under a dome. Additionally, they are also a kind messenger to the other presenters – e.g. they praise some elements they saw during another day of their training with another presenter and might encourage the other presenters to try those sequences themselves (Fig. 4). From time to time during the training period the dome or technical manager will also give training lessons to test the progress of the trainee as well as introduce the important workflows, thematic emphasis and the philosophy of the dome. Of course, the trainee also brings along his or her own skillset which will develop during the training. At the latter stages those skills will also have an impact on the existing presenters and give them new inputs of their own. This knowledge transfer during training is an efficient way to keep all the presenters up to date about the possibilities of the system. Due to them usually operating alone in my dome in Lucerne this presents one of the rare occasions where discussing presentation techniques and technical know-how is possible during their daily sessions.

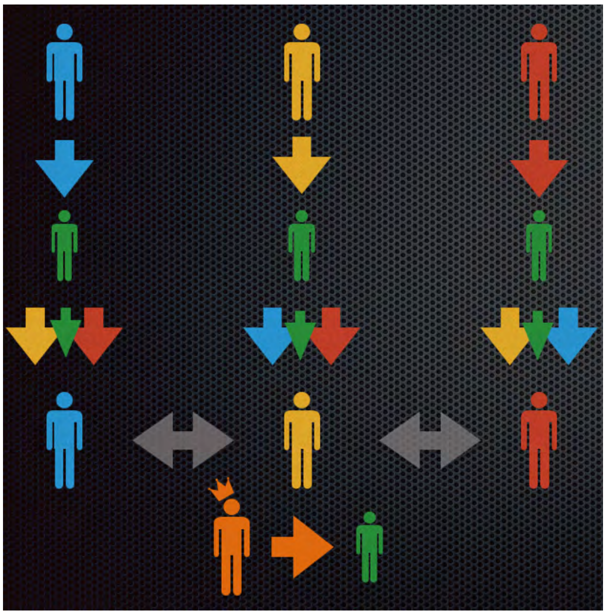

Figure 4 – Knowledge transfer during the training of new presenters (green). As different presenters possess different skillsets (different color codes, see Fig. 3) the training of a new member of the team also results in a knowledge transfer between the other presenters. Additionally, the dome or technical manager (orange) will give introductions to the deeper layers of the system and trains the must have workflows and skills. Note: Presenters in Lucerne usually do operate alone.

III. IMPLEMENTATION OF THE LIVE CONCEPT

III.1 Basic concept

The live format I had in mind also required a lot of work from a technical point of view. The concept is a modular one. The presenters must have access to the necessary tools to change the subject of their presentation rapidly and be able to cover many different topics while still be able to extensively focus on one particular topic if they desire. Imagine it as a jigsaw puzzle. My team has a lot of pieces available (see Fig. 5). But what the final picture will be is essentially their responsibility. The pieces fit together in several ways so many different combinations are possible to design a complete show.

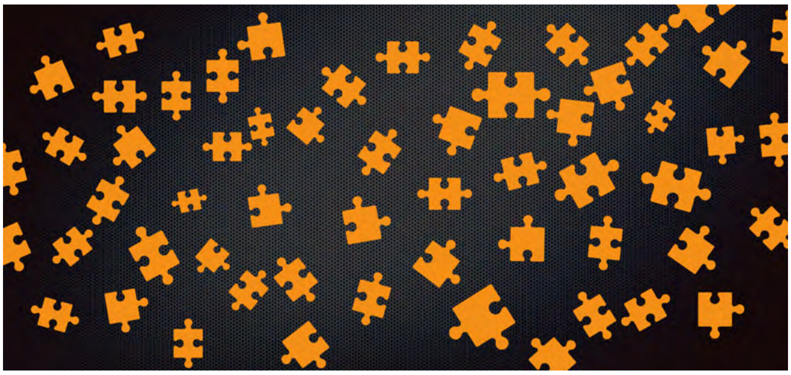

Figure 5 –The implementation of the intended concept for live shows can be compared to a jigsaw puzzle.

III.2 Technical implementation of the concept

Having a suitable all-digital system at my disposition, implementing my concept of live shows required technical skill and some creativity. I decided to extensively use so called "Control Panels" in Digistar. This allowed me to design theme-based collections of system commands and small scripts. The latter were written in a way that they are applicable in a wide range of different situations and are not tied to certain prerequisites. For example, I implemented the Earth fly to-script so that it can be used for takeoff from the surface as well as flying back from somewhere else in space. To minimize maintenance and speed up the time required to implement similar sequences, scripts doing similar things are based on the same templates. This modular approach also allows to react to recent events as all it takes to show this to the audience during a presentation is a new mini-script with the respective content. The presenters are able to adjust their existing workflows very easily and effortlessly. See Fig. 6 and 7 for two examples of modular presentations with different topics based on control panels.

As an additional benefit, Control Panel pages in Digistar can also be used on a mobile device like an iPad. Especially for large domes like mine this allows for much closer interaction with the audience like it is possible and practiced in smaller planetaria. Issuing commands is no more limited to the computer console at the presenter desk but can be done next to the visitors. Interacting with them is a lot easier and reaction time to comments or suggestions is significantly decreased. Further, the audience better notices and acknowledges the performance of the presenter as they see him or her while presenting a live show.

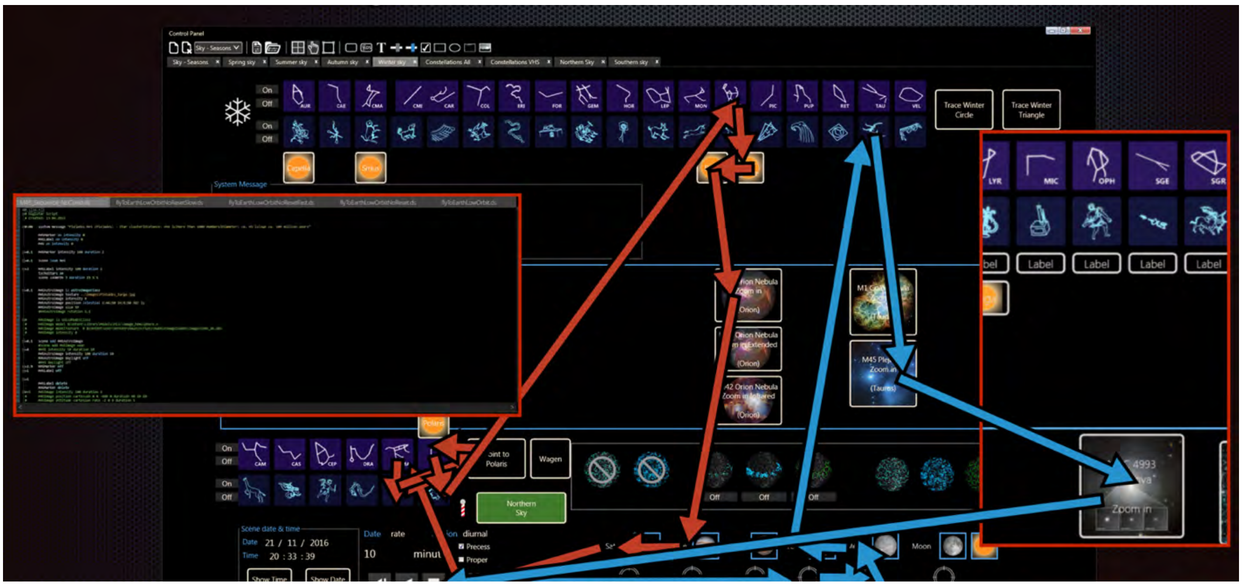

Figure 6 –A Digistar control panel page which shows two possible sequences during a show which presents the current night sky. Underlying every button showed in this image is a short script (red box on the left). This modular approach also allows for spontaneous alterations if e.g. something is of special interest during a show or a recent discovery has to be covered. In this example this is represented by the HST picture of the kilonova in NGC 4993 tied to the discovery of gravitational waves – which we showed to our audiences the day after the release of the image.

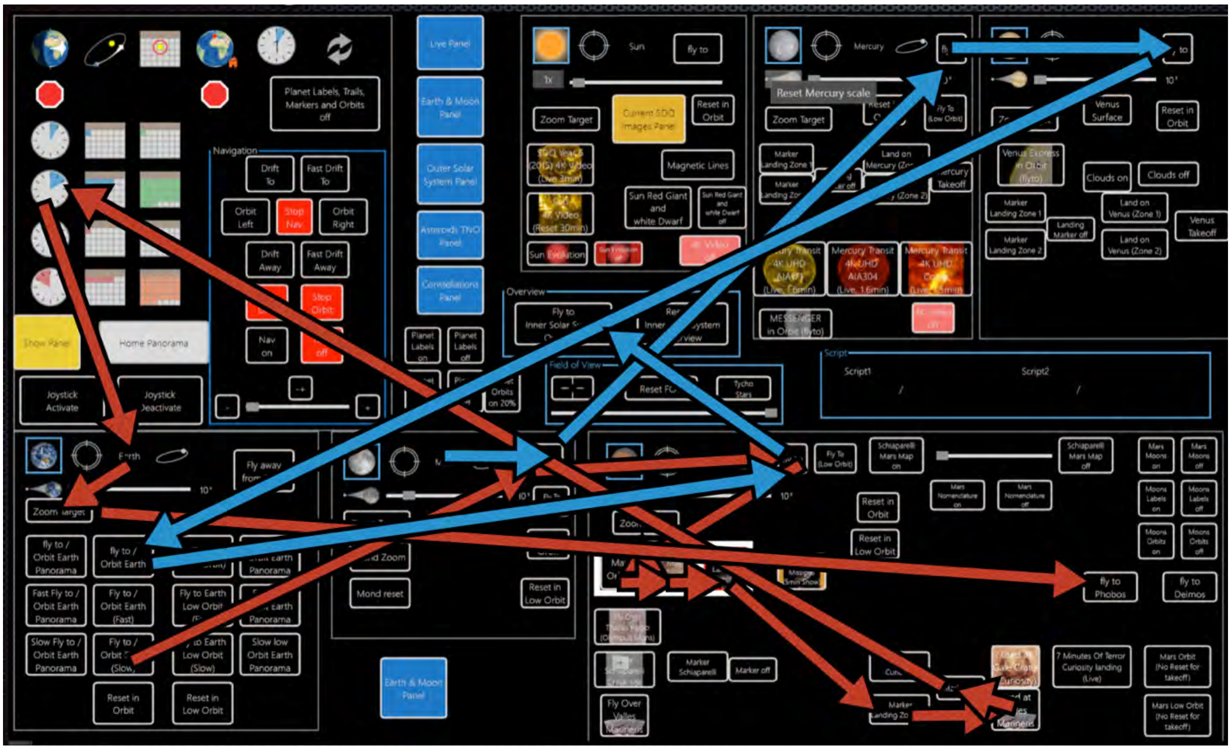

Figure 7 –A Digistar control panel page which shows two possible sequences for the space themed part during a show. The first presenter (red) first flies into Earth orbit, visits the moon then Mars. After showing the probes and landers a landing at Valles Marineris is done and the Earth is shown during Martian dusk. The other presenter (blue) goes directly to the Moon and afterwards flies from Mercury to Venus, Earth and Mars before presenting an overview of the inner Solar System.

IV.KEEPING AND SPREADING THE KNOWLEDGE – STRATEGIES TO TRAIN YOUR PRESENTERS AND KEEPING THEM UP TO DATE

Having a complex system which gets updated and expanded frequently is challenging regarding knowledge transfer to and within the team that operates it. This is especially true if the team members do operate alone in their daily sessions and do not have regular contact with the others. I encourage my presenters to practice before each show block so they train themselves and have an opportunity to try new workflows and elements for their live segments as well as self-confident in running the system and their shows. To ensure knowledge transfer I implemented four different methods (see Fig. 8).

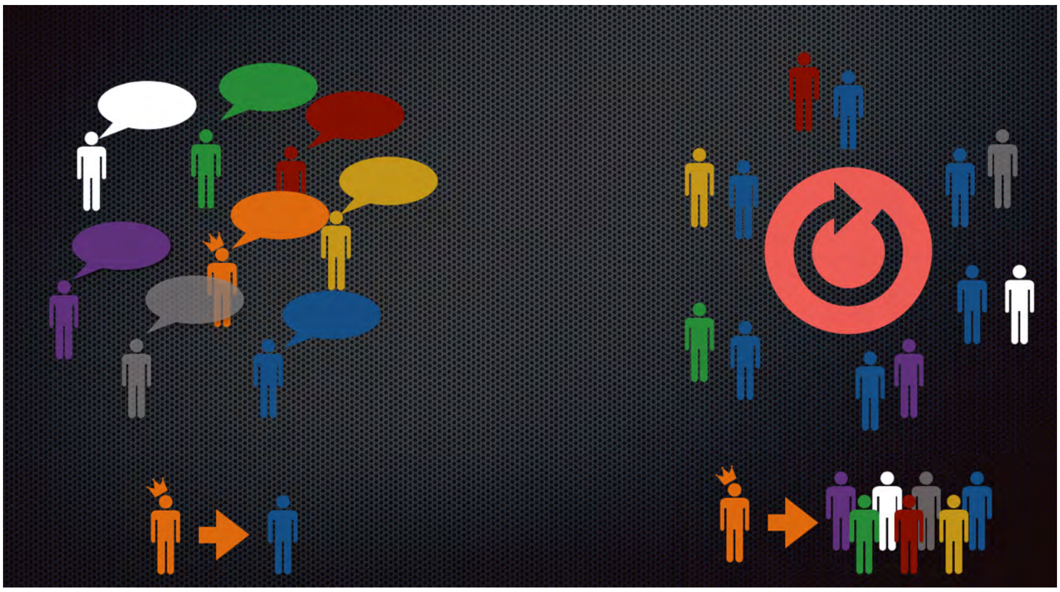

Figure 8 –The four primary methods I use to share experiences, retain the knowledge and inform my presenters about new content or changes in existing one. Clockwise from top left: Regular meetings and Workshops, periodically shared presentation duty, periodic electronic newsletters and individual coaching.

IV.1 Periodic Workshops and instant messaging

It is of outermost importance that the team members see each other regularly or at least get reminded that the other presenters do exist. I schedule quarterly meetings where every presenter is invited. We use this for training, discussion of concepts, workshops and demos. Usually, these meetings take much longer than anticipated but that is okay – I'm very happy to give my team the opportunity for exchange and discussion. The "light" form of this for urgent or small topics is instant messaging: I created a WhatsApp group for my team where general things can be shared and questions asked. The latter proved to be very popular and handy. The team usually is disciplined so that usage of this form of communication is professional and efficient.
With this method you overall improve the exchange of best practices as well as the discussion and presentation new workflows.

IV.2 Shared presentation duty

The second way to ensure knowledge transfer is something similar like we do during training of new team members. I plan regular occasions where two presenters work on the same day so they can distribute the different shows among them and watch each other presenting. I encourage honest feedback and I'm happy when I see some methods or sequences I know from one presenter done by another after such a period. Also, I suggest to spontaneously visit other presenters and label this as paid training to boost such initiatives.
This is the preferred method to promote transfer of knowledge concerning presentation techniques and operating the system due to the participants being on the same level but with a different skillset which also proves to be very efficient in training new team members as seen in section II.

IV.3 Periodic newsletter and blog

As I am the one that updates and adds new content to the dome system, my presenters usually do not know about it. I therefore had to find a way to keep them up to date about the different capabilities and, more importantly, changes to the system. I initially did this by sending an email newsletter to my team. This worked reasonably well but had a major disadvantage that past messages were hard to archive and to be found again. I recently switched to a blog format which keeps all the necessary information in one place and is easily search- and taggable. I use this format to inform about organizational things as well as new content and updates or changes to the system.
With this I ensure everyone stays informed and can adjust their live shows accordingly if one wishes, so this spreads knowledge for technical and organizational things and builds a kind of documentation for the current state of the system.

IV.4 Individual coaching

The most efficient way to teach a presenter about the capabilities of the system is individual coaching by me. This of course is time-consuming but very well worth the effort. I usually show them new stuff I'm currently working on or I've just finished and is ready for use by them. My presence also encourages them to ask questions, request sequences they could use and give feedback about the way things are going in general. Additionally, I often do sneak in their live shows to avoid them becoming nervous if they know I'm present, so I'm able to give honest feedback regarding their performance afterwards.
This method ensures the direct dialogue between me and my presenters so that I can adjust my plans and management strategy based on the needs of my staff. It is also the best way to present new content for live shows to the individual presenters and train them specifically in least developed skills.

ACKNOWLEDGMENTS

I'd like to thank my team of presenters in Lucerne a lot. We push each other forward and achieved a unique setting for performing live shows.
Also, I'd like to thank many colleagues around the world and the great team at Evans & Sutherland which inspired me during long and intense discussions to think about methods and ways to optimize my live show format and provided their own sequences through cloud services and other means to use in our shows.

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Figure 6 & 7: Captured from Digistar 6 by Evans & Sutherland, http://es.com

Star Safari

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Biography:

I am the Education Coordinator for the Abrams Planetarium in East Lansing, Michigan. I have been at the Abrams Planetarium for nearly 17 years. Before that I worked part-time at the Sharpe Planetarium in Memphis, Tennessee while in graduate school at the University of Memphis.

Abstract:

On Saturday July 11, 2015 the Abrams Planetarium along with Lansing's Potter Park Zoo presented a special live show, ***Star Safari*** for the first time. This show introduced the audience to animal constellations in the night sky and to real animals from the zoo. Audience members heard stories about the animal constellations and what the zoo is doing to help with their conservation. Zoo docents had many small animals on display in the planetarium lobby before and after the show.

Star Safari has become a semi-regular event with the Potter Park Zoo. There was no charge for admission for the first showing, as the event was meant to publicize the planetarium and conservation efforts underway by the zoo. With later presentations the charge was the standard planetarium admission price. It was limited to 140 participants (the seating capacity of the planetarium) and published advertisements for the show warned of limited seating. A second show is usually planned if too many people arrived, but normally is not necessary. An average of around 80 people, mostly families come to the show. The planetarium show is scheduled one hour, but can last a little longer. Some guests remain in the lobby for about thirty minutes after the show.

In the lobby of the planetarium tables are set up to allow zoo volunteers and docents to show some of the animals that they use for education outreach. The animals presented included different types of birds, a rabbit, a tortoise, and several snakes and reptiles. The animals used are similar to the constellation animals that are presented in the theater. Guest are able to interact with some of the animals and docents tell them more about the animals. Also in the lobby, we will sometime have musical entertainment. John French from the Abrams Planetarium, along with his ukulele band perform animal themed songs, if they are available.

The presentation in the theater is live and includes me and the representative from the zoo, who happens to be my wife, Jennifer Horvatin. As I take the audience members on a tour of the night sky, my wife then talks to them about the real animals and their connection to the zoo. We start with the summer sky and worked our way through the seasons. Included in the show are the circumpolar animal constellations and even a quick trip to the Southern Hemisphere. We show most of the animal constellations, but try to focus on the ones that the Potter Park Zoo actually have. After I locate the constellation on the dome, I also bring up a picture of the animal. Most of these pictures are animals at the zoo itself, although a few were stock images found online.

Along with each constellation I tell the classic stories associated with them, if they have one. Of course some of the modern constellations, such as Lynx and Lacerta do not have as interesting stories as the ancient constellations. To enhance the presentation some constellations not used by the I.A.U. are also introduced. These animal constellations include Native American and Chinese star mythology. The Chinese mythology include the four great sky animals: the Blue Dragon of Spring, the Red Bird of Summer, the White Tiger of Fall, and the Black Tortoise of Winter. I use the constellation images found in the Digistar 5/6 system created by Samantha Galvez at Colgate University.

For the Native American mythology I use images (with permission) created by Annette S. Lee (planetarium director, St. Cloud State University). These images were taken from D(L)akota and Ojibwe sky maps and converted to images for use in the Digistar 5/6 system. Included are D(L)akota images of a tortoise (Pegasus), an elk (Pisces), a salamander (Cygnus), and a snake (near Canis Major and Carina). The Ojibwe images include a crane (Cygnus), a fisher (Big Dipper), a Moose (Pegasus), and a loon (Little Dipper).

Other miscellaneous animal constellations are also used during the show. I present an image of the Mayan bat-god Camazotz (Ophiuchus) along with a regular constellation outline of a bat. I also have an image of a caribou, used by many Inuit people to identify the stars of the Big Dipper. The Tuareg of northern Africa see the Big Dipper as a camel, so I also use that image. One of the final constellation images I use is the obsolete Noctua, the owl. This seldom mentioned constellation was at one time placed on the end of Hydra's tail. After I mention this constellation, I slowly bring up some red lights in the planetarium and my wife will bring in the zoo's owl Oslo. This is a highlight of the show. After the presentation she again presents the audience members the owl in the planetarium lobby.

In conclusion, ***Star Safari*** has been a highly successful program for both us and the Potter Park Zoo. As revealed in a post-participation survey the audience thoroughly enjoyed the show and had fun interacting with the education animals in the lobby. A sensory friendly version of the show has also been presented, using more theater lighting and lower volumes on the microphones.

Acknowledgements:

- Jennifer Horvatin, Assistant Education Coordinator, Potter Park Zoo, Lansing, Michigan.
- Dr. Shannon Schmoll, Director, Abrams Planetarium, Michigan State University, East Lansing, Michigan.
- Val Johnson, photographer
- Carolyn Shulte, photographer
- John French and the Punch Drunk ukulele band

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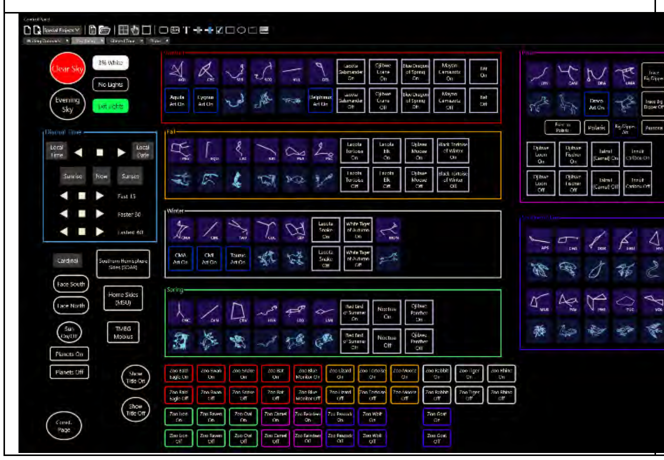
Ojibwe Sky Star Map Constellation Guide: An Introduction to Ojibwe Star Knowledge. 2014. Annette S. Lee, William Wilson, Jeffrey Tibbetts, and Carl Gawboy.



Presenting the Subatomic: Can the Audience Be Your Guide?

Fiona Hughes, Rose Kelly, Julianna Meyer, *University of Notre Dame du Lac (USA)*
Email: kdavis10@nd.edu

BIOGRAPHIES

Fiona Hughes will attend Purdue University in West Lafayette, Indiana, USA, to major in Chemical Engineering. She enjoys spending time going on hikes, hanging out with friends and family, and listening to music. She is also interested in learning more about how planetariums are used in various educational settings.

Rose Kelly is a rising freshman at the University of California, Los Angeles, USA. There she will be pursuing a double major in Philosophy and Computer Science. She enjoys nature and the theatre. She is passionate about planetariums and aspires to keep working with them throughout her college career.

Julianna Meyer is going to be a freshman at the University of Notre Dame du Lac in Notre Dame, Indiana, USA. She intends to double major in Neuroscience and Behavioral Studies and Psychology. Her passions include art, science, baking, and film. She enjoys learning about the multiple uses of planetariums and hopes to continue presenting in them in years to come.

ABSTRACT

The QuarkNet Center at the University of Notre Dame has created a set of digital assets illustrating the subatomic world.These assets illustrate how particle accelerators such as the Large Hadron Collider (LHC) investigate the smallest constituents of the universe. The high school students and teachers from the 2017 QuarkNet summer program developed a unique way of presenting these materials which asks the audience to guide the presentation. The three graduating high school seniors, Fiona Hughes, Rose Kelly, and Julianna Meyer will treat the audience to an example of this presentation style. Are audiences better engaged and do they learn more when offered the chance to follow their own curiosity? The Presenters will explore the audience's preconceived notions of the subatomic world and use the assets as tools to illustrate concepts in real time including genuine data from the Compact Muon Solenoid (CMS) detector at the LHC. The presenters will also update the audience on results from research projects to test the educational effectiveness of these assets. The QuarkNet program is an NSF-funded partnership between Fermilab and the University of Notre Dame that seeks to develop America's technological workforce.

INTRODUCTION

The majority of planetarium presentations follow a highly structured path through their material, precisely planned out well in advance by the speaker. But what if that all changed? This is exactly what we explored this past summer through the Quarknet Program at Notre Dame. Over the years, the Notre Dame QuarkNet program's Digital Visualization Theater (DVT) group has had the task of creating and presenting an education show on Particle Physics via 3D models and animations through software called LightWave 3D and use of the DVT (50-foot-diameter dome utilizing Sky-Skan Definiti Digital Fulldome). The presentations were given to a wide range of audiences and therefore presented a challenge, as it was hard to change the presentation to fit a certain audience when all there was previously was a canned script. At the conference we will share how we decided to change the way we give our presentations from following a script to having an audience-led extemporaneous talk. The adjustments we made to make this presentation more interactive were designed to hold our audiences attention, allow them to connect with the material, and give them the opportunity for immediate application of what they were learning.

DISCUSSION

Previously the Particle Physics Show followed an eloquent script that was the product of many hours of brainstorming and editing. The script allow for a controlled and efficient communication of the material. However, our goal with the DVT project was to go beyond a dissemination of information; we wanted to educate and spark the intellectual curiosity of our audiences. This is where the hub--the starting point for our presentation--comes in. The hub previews the three main parts of our presentation by showing an asset from that part accompanied by a brief description of what's in store there. The sample assets we used in our hub can be seen in Figures 1, 2 and 3 below. Based on this information the audience picks what they want to learn about first, and then second and third as we return to the hub after each section. Following this "Choose Your Own Adventure" format, the audience truly

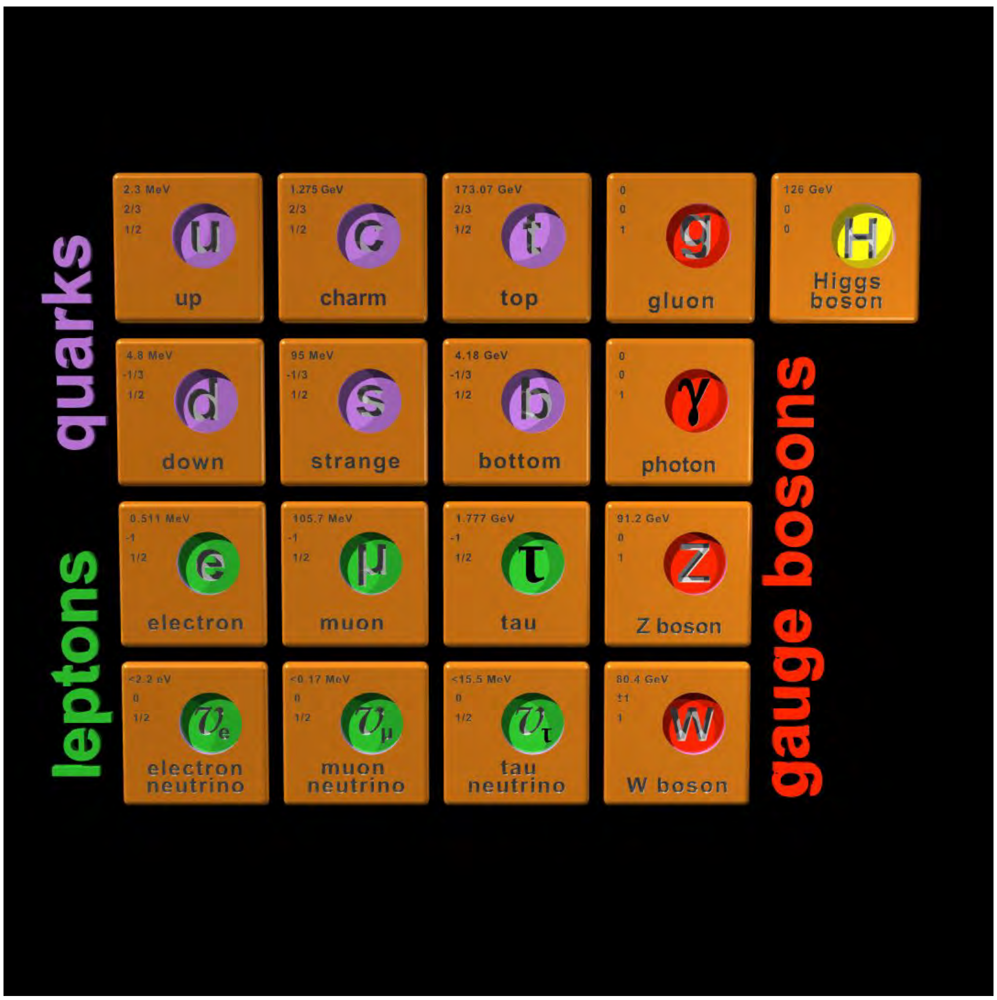


Figure 1. The Standard Model.

becomes the guide. Our goal with the hub was to engage the audience in the presentation; we wanted them to feel like they were on a journey with us instead of feeling like bystanders. By having the audience choose the material, they learn they are put in an active position and become more invested in what we have to share, directing their

focus and interest towards the topic at hand. Additionally this format emphasizes the community aspect of the planetarium learning experience, as the audience must choose together what the group will explore next. Putting an element of control into the hands of the audience creates a potent learning environment comprised of the trifecta of the flexibility of self-guided study, the expertise of a human teacher, and the communal atmosphere involved in being part of what could almost be called a team, as the audience makes decisions and learns together. So while it may
be less structured and organized, the quality of the educational experience is far greater.

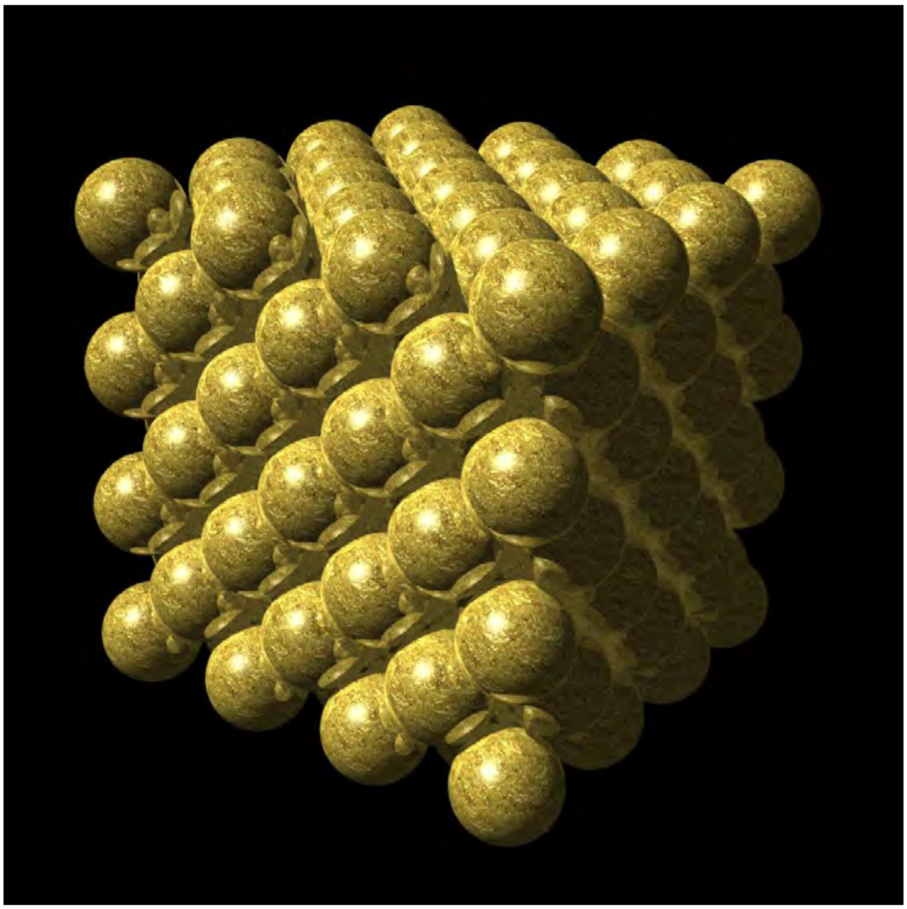


Figure 2. An atom of gold.

While we were given the freedom to create new models and animations for our presentation, previous years of DVT groups passed down their work to prevent us from having to begin completely from scratch. Ordinarily, the presenters of the material would show the larger portion of the topic, for example the Large Hadron Collider, and narrow in from there. A set point A would lead to point B, never deviating off script. If the audience had a question it would either get answered along the way or wait until the end. Due to the intellectual density of the topic of particle physics, we immediately identified a problem with this method of presenting. We knew to produce the greatest impact, we needed to cater to the audience's needs, rather than telling it to them in the order we perceived they needed. This posed its own unique challenge: how do you take a model made for a specific script and alter the presentation around it in a way that instead allows the audience to choose what comes next? Our solution revolves around questioning. Allowing our audience to pose questions as they come up with them gives the freedom of exploration. It makes learning the material less confusing, and helps it flow in a specific way catered to them. For quiet audiences, sometimes questions need to be posed, but for louder groups they will naturally come up. These questions help us use our models in an interactive fashion. Their questions lead to our answers and prompt transitions from one subject to another. Instead of showing a model and telling what comes next, the audience has the freedom to explore their educational experience on their own terms, observing the model and asking questions to start a discussion. Using this method is challenging for us as presenters, having to know more material than for a scripted presentation and being ready to act on our feet, but it is rewarding to our audience that is receiving a unique learning experience and getting the most out of their DVT show.

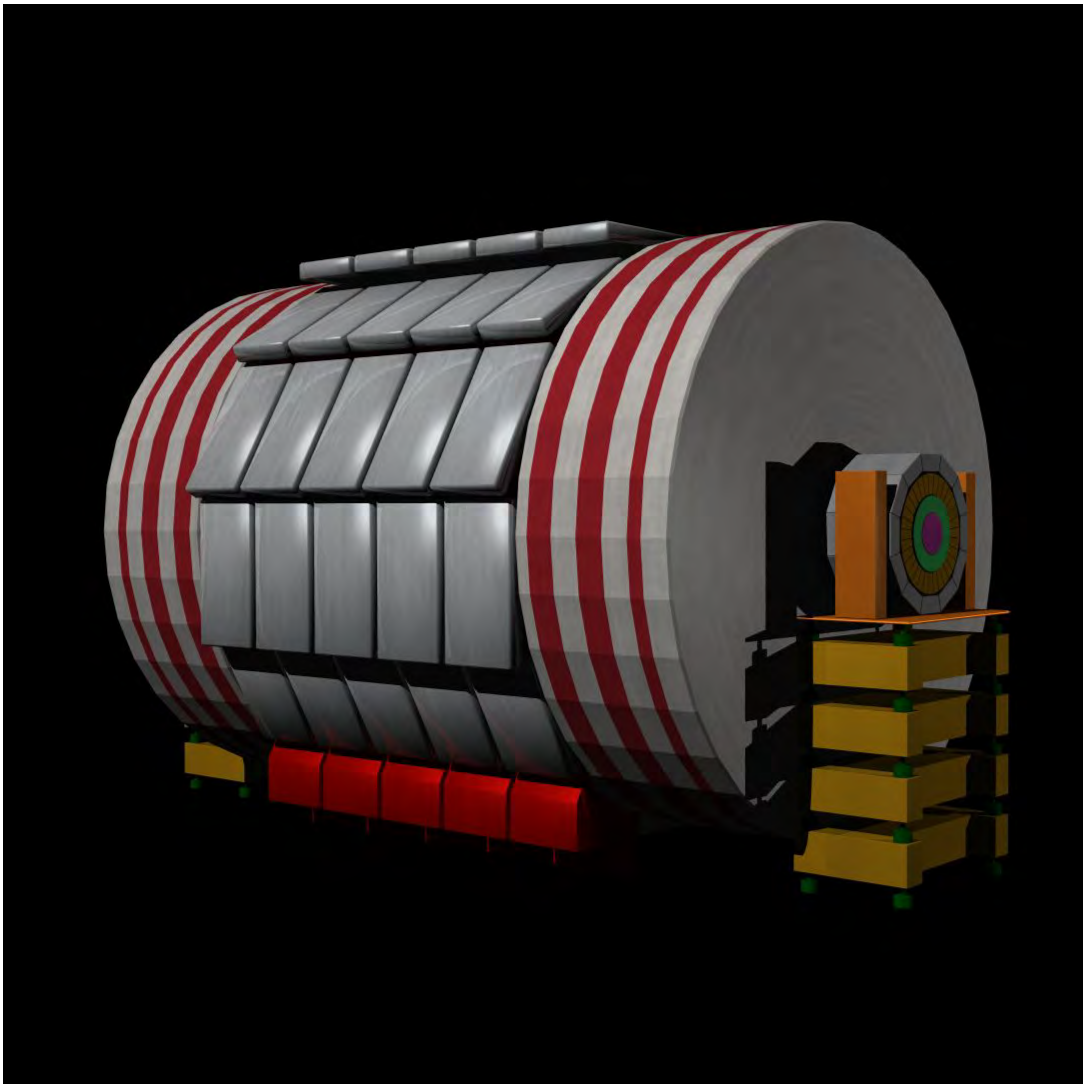


Figure 3. The CMS Detector.

Throughout the scripted presentation that was previously implemented, the audience would be exposed to many different animations and be told what they are viewing through detailed explanation. However, this was soon realized to be overwhelming for the audience who would be showered with a deluge of information in a short period of time. Recognizing this shortcoming, we decided to shift it to a more interactive style by having the audience immediately apply the material they learned to a different animation. The key element to this transition was asking questions. Once we showed an animation to introduce an idea, we would then show another similar animation and ask questions of the audience to turn it into more of a discussion. For example, one of the sets of animations that we typically show at the end of the presentation is that of an original data event of a particle collision producing the

Higgs Boson. Leading up to this animation we show generic simulations of what a particle collision between two proton bunches would look like and what results from these particle collisions: many more particles. From there we discuss the behaviour of the different types of particles as they travel through the detectors, giving the audience context and a foundation for understanding a real data event. Finally we would show the Higgs Boson data event and ask the audience to identify particles and answer questions about what they think they are seeing on the screen in order to solidify their understanding of particle collisions.

Although there are many benefits to extemporaneous talks and audience-led interactive discussions, there are naturally some cons as well. With the absence of a script, the presenter loses the ability to use flowery language, and the presentation itself loses a sense of structure. Additionally, there is more room for error and miscommunication as there is not a set prompt that we are following, and questions we are not necessarily prepared for may arise from audience members. However, overall we have found the benefits of this style to far outweigh these minor issues. This form of presentation allows the audience to explore and discuss what they are interested in and therefore keeps the audience engaged for the duration of the presentation. By giving us the freedom to change what we focus on and what level of complexity we will go to, transitioning to an extemporaneous talk has allowed us to cater to the unique needs of every audience we may present to. The atmosphere that is created is exemplary of the concept that the interaction between presenter and audience is essential to ensure the audience grasps the material given to them. We have found this to be a highly favorable way of teaching complex material such as particle physics, and we hope that others will begin to see how extemporaneous talks are suitable for audiences of all varieties.

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Planetaria, are they for everyone?

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Shaaron Leverment*, British Association of Planetaria* & *Explorer Dome Planetarium*, Email: shaaron@explorerdome.co.uk

BIOGRAPHIES

Tina Ibsen is Head of Science and Outreach at Tycho Brahe Planetarium in Copenhagen, Denmark. She leads a team responsible for everything related to the scientific content.
Shaaron Leverment, founding director of Explorer Dome, manages national STEM programmes across UK through the British Association of Planetaria and the UK Association for Science and Discovery Centres (ASDC).

ABSTRACT

As planetarians we strive to make abstract concepts accessible to a wide audience. But do we really design our communication to reach all? Or do many of us revert to more traditional methods of communicating the science that we all love. In this workshop, we will look at the background evidence and new methods to include groups that are underrepresented at our institutions and in wider STEM research fields and industry.

INTRODUCTION

The space industry in Europe is strong and growing, offering innovating services and providing huge benefits across science, the economy, government and society (UKSA, 2015). There is a clear and growing requirement for more graduates and technicians with relevant STEM skills and qualifications.

Within our sector, we have a role to play in enhancing the wider skills, interest and knowledge of the public and inspiring the next generation of scientists through informal STEM education.

However, research clearly suggests that certain sections of society do not consider a future STEM career, or even a visit to a science centre or planetarium as something that is relevant to them (Archer et al, 2014)(Dawson, 2014, 2018). Despite it becoming increasingly important to address the skills gap which threatens to limit the growth of the STEM and space industry sectors, we appear to be leaving large sections of society behind.

When it comes to school groups and family science learning, planetaria can play an important role in raising family 'science capital' with research finding a clear relationship between a student's level of science capital and their future aspirations in STEM subjects (Archer et al, 2014). Activities that engage parents and teachers and promote positive role models to increase diversity in STEM have now become strategic priorities and clear recommendations for government (CaSE, 2018), and national funders are already turning towards projects and programming with greater inclusion of disadvantaged and underrepresented groups.

Therefore, considering the persuasive economic, creative, social mobility and equity arguments for STEM (Walker & Zhu, 2013), we now need to consider diversity, social inclusion and greater participation at the very heart of our future practice.

This workshop aims to take the first steps to share what we know and reposition what we do (and how we do it!). The stunning visual content within planetarium domes is simply not enough if we now want to make a difference to who we are engaging with the space sciences that we all love.

I. UNDER-REPRESENTED GROUPS IN STEM

II.1 First Do No Harm

At the last British Association of Planetaria meeting, Shaaron Leverment led a session entitled 'First do no harm'. Should we try to do more as planetarium domes (of all sizes), to avoid practices and language that may inadvertently lead to people of different ages, genders, ethnicity, disability or socio-economic inequality, feeling that space science is 'not for them?' (MacDonald, 2014)

Planetaria need to be looking at their policies and strategy, their content, accessibility, partnership building and their own workforce to answer this question, and we are all on our own journey to promote awareness of gender and societal equity at different levels by This includes challenging stereotypes, addressing unconscious bias (Frith, 2015) and promoting confidence for all people to feel empowered to consider science to be a valuable, relevant, attainable and enriching aspect of their daily lives and culture.

At the British Association of Planetaria (BAP), in answer to the question posed last year, a project to promote the science, engineering, people and stories behind the James Webb Space Telescope (supported by the Science and Technology Facilities Council) have devised a 2-year project to promote STFC science alongside greater inclusive practice within UK planetarium domes. This project is in its infancy, (starting in June 2018) and with an emphasis on mobile planetarium outreach and work in schools. Within this session we will discuss our aims, and surface what the group already knows in how we can address some of the challenges we face.

Based on building close partnerships and collaboration with those that work within our target audience, this programme will being in consultation, co-creation, staff training, reflexive practice and impact evaluation to steer the content production and delivery of planetarium resources towards more inclusive practice, with an aim to provide evidence of change.

II.2 Gender Diversity in STEM

In the western countries only one in three graduates in STEM is female. This has changes very little throughout the last 15 years. And this number is even lower when we take out the life-science fields. A diverse student body is shown to foster an academic, cognitive and social growth of all students (Gurin, Dey, Hurtado, & Gurin, 2002). This is just one amongst a number of other benefits of diversity. However despite a number of initiatives from the EU FP6-funded GAPP (GAPP Report: https://cordis.europa.eu/result/rcn/48741_en.html) to the project *Science: It's a girl thing!* started in 2012, we have seen very little difference to the number of girls and women pursuing a career in the hard sciences.

Many have now started to argue, that the way we talk about science is masculine gendered, and thus exclusive for a number of different groups (Brickhouse, 2001 p. 283). Thus, if a person does not identify with the often masculine characteristics presented by the STEM fields, it might force them to reject STEM completely, or face what (**Faulkner, 2000**) refers to, as gender inauthenticity, where they feel like they need to undermine their gender in order to fit in.

In Denmark we see a lack of women in many STEM fields, including astrophysics and space technology. Despite seeing an increase of students opting to study physics, there has not been an increase in the number of women choosing this profession (see figure 1).

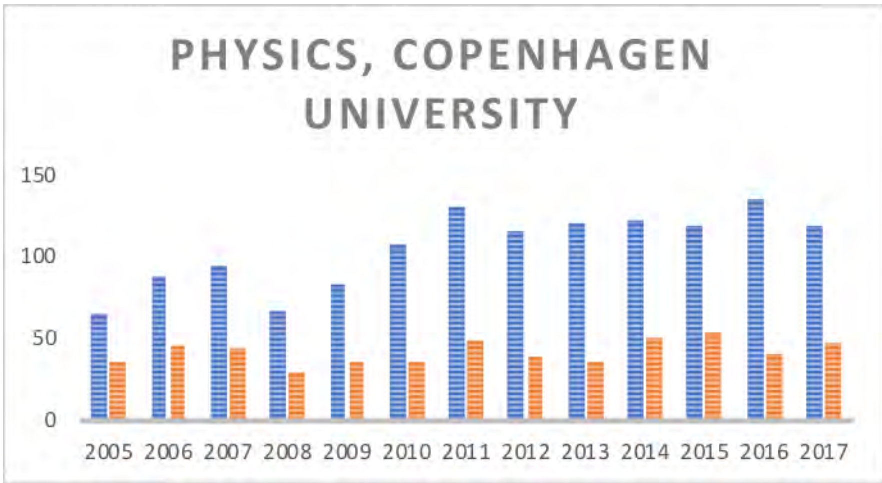

Figure 1: The distribution of men and women studying physics at Copenhagen University. Men are marked in blue and Women red.

II.3 Case Study: Made in Space

At the Tycho Brahe Planetarium in Copenhagen, a new exhibition about astrophysics, Made in Space, opened in February 2018. This exhibition deals with a number of complex themes, such as Big Bang, black holes, dark energy etc.

In order to make this exhibition accessible to all, the Tycho Brahe Planetarium had a PhD student taking part in the project, working on making the design and narrative of the exhibition as accessible as possible. Using the theoretical framework from post-modern feminism, the result is an exhibition unlike any other in Denmark. Tina Ibsen has been leading the content work for the exhibition, and she will share some of the results from design and content work.

In the exhibition *Made in Space* that opened at Tycho Brahe Planetarium in February 2018, we have worked with diversity and inclusion principles from the Horizon 2020 project *Hypatia* to create an exhibition that would be more welcome to a larger number of visitors. The team at Tycho Brahe Planetarium worked with a PhD student, to ensure the principles were incorporated to the very core of the development and design work. The PhD worked with non-users of the planetarium, to make sure that the exhibition would be appealing to people that would not normally visit.

ACKNOWLEDGMENTS

‘Are Planetaria for Everyone’ would like to acknowledge the EU Horizon 2020 Hypatia Project, the Royal Society’s work on Unconscious Bias and the Institute of Physics for providing the theoretical background and data that supports best practice discussed within this session.

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Next-to-planetarium exhibition's educational use

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BIOGRAPHY

Manager of European Space Education Resource Office (ESERO) in Poland. Apart from the educational aims, he is a planetary geologist with an interest in small Solar System bodies' dynamics. During university studies, he participated in student Martian rover challenge. Experience gained is now used for the organization of Cansat competition in Poland.

ABSTRACT

Approach to the idea of educational activity introduction in the proximity of the planetarium dome is being discussed. Paper illustrates a decision-making process, leading to the development of the final educational activity, its grounds, reasons for reiterations, and outcomes. It might be a useful case to be considered when planning to pursue a similar goal – which in this case was to increase visitors' interest in the exhibition established around the planetarium dome.

INTRODUCTION

Copernicus Science Centre (CSC) has a planetarium dome, Heavens of Copernicus, which is spatially dispatched from the main exhibitions. This can cause a situation when the visitor base is different for Planetarium and the Science Centre. Therefore, when visitors are coming to the Planetarium, it might not be obvious to them how to find themselves among the exhibition content.

Figure 1 – Spatial outline of the CSC

Exhibition which surrounds the planetarium dome is named 'Look: Earth!' and is mostly concerned with astronautics, rather than astronomy. The overall theme of the exhibition is space exploration and space research, including how they affect our day-to-day lives. The experience starts down on Earth, as you manage your own rocket launch. There are opportunities to enjoy the view from a space station in real time, to examine real satellite photos, to learn about the number, speed, and altitude of the satellites circling the planet, and also to find out why they do not fall down to Earth, and so on. It contains 20 interactive exhibits and numerous models, photographs, and dispersed content. Due to the effect that visitors are mostly interested in the planetarium screenings, exhibition experience surges in visitor count, right before the screenings. In other times, it is not very crowded as it is mostly regarded as a 'waiting room' rather than the point of interest in itself. This situation has been identified as a starting point for a change in school groups' visitor experience.

I. TAILORING THE ACTIVITY

I.1 Understanding the baseline

Heavens of Copernicus is a great prospering planetarium, which attracts about 230 000 visitors a year, produces award-winning movies and organizes a lot of special events gathering large number of interested people. Nevertheless, dome lives its own life, and the exhibition around it – its own. Our entry point was the realization that people attending planetarium activities rarely interact with the exhibits more than to just pass time (which was the purpose of the exhibition in the first place, but after several years, a window for another way of utilization has opened). Even more, school groups visiting planetarium for the screenings and regular CSC exhibitions, rarely used Look: Earth! Exhibition actively and with enough time to develop mental constructs connected with concepts visualized by the exhibits there.

I.2 Setting the goal

There were several aims that were identified as worth pursuing at the beginning of the planning process. We wanted to increase the number of visitors that actively interact with the exhibition, with as much educational gain as they can get from its constituents. This active participation could be managed through organized workshops which would fit into the CSC's commercial offer and therefore stand as extra budget influx.

From the beginning, we have wanted to develop resource in dual form – not only the paid version, but also to release an open access scenario of exhibition use for the teachers, with listed curricular link of the exhibits, which prove helpful when planning one's lesson (in this case, well outside the classroom).

I.3 First iteration

In the first place, we wanted to introduce a product, which would offer groups of our visitors an active yet guided way to get familiar with the ideas presented by the exhibition's content.

The idea for the workshop – called Space Lesson – has been to provide meaningful 1,5 h activity for a school group of lower secondary students.

Activity focuses on the student exploration of exhibits and concepts presented by the exhibition, however, it start with an mini-lecture on one of subjects (i.e. electromagnetic spectrum, light pollution, data transmission, etc.), selected from the list by the explainer carrying out the workshop. Then, participants are divided into groups, which are given a task of finding any information they can spot on one of the themes (weather prediction, Earth observation, Space in art & pop culture, etc.). Every group gets one, separate theme. Explainers are ready to help students when they encounter any problems. Students take notes on the Activity Cards they are given at the beginning of the workshop. After some time, students are gathered in one place in the exhibition area (preliminary choices are presented in Fig. 2), and discuss in their groups, what they have experienced in relation to their assigned themes. Afterwards, explainer asks every group to present their gathered information using flipchart, to the rest of the class. As all of them complete their presentations, discussion begins on different points of view from which students has been looking at the exhibition and space in general.

During this kind of workshop, students not only gained knowledge independently, while discovering the phenomena presented by interactive exhibits, but also develop soft skills needed to discuss their ideas and then present their own observation before the class.

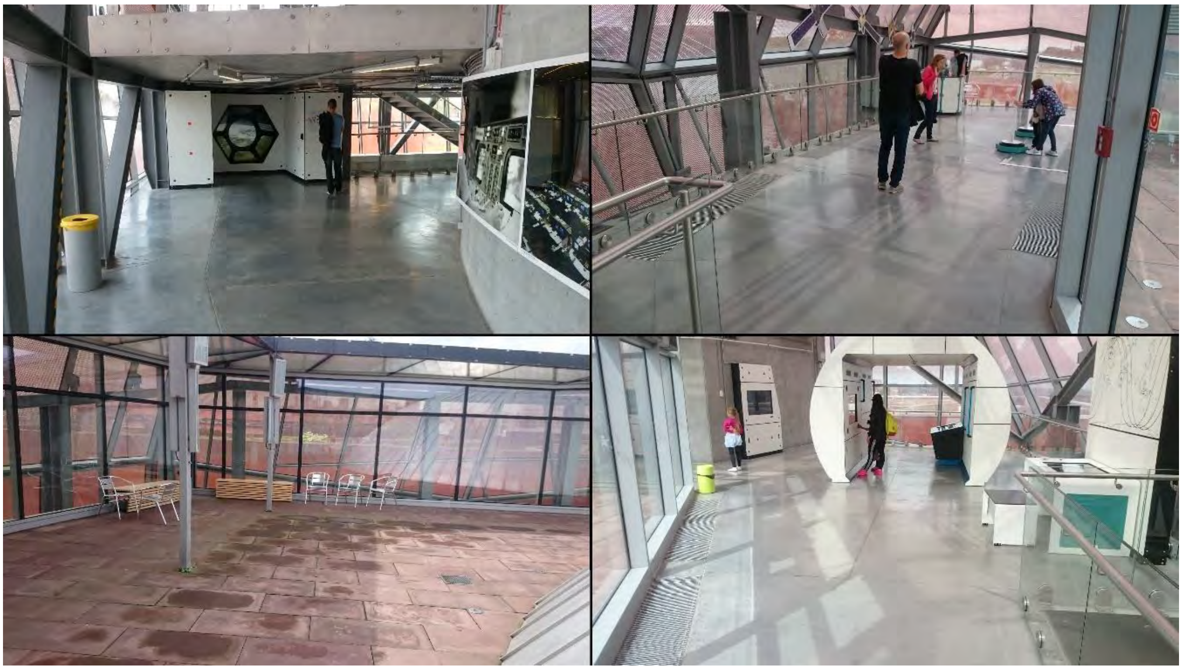

Figure 2 – Spaces considered to harbor workshop activities

The formula for the workshop has been tested during the "Space at School 2017" teacher conference. We invited participants to take part in the pilot version of the workshop. We gathered 25 willing teachers, who filled the places which would normally belong to the students. This experience gave us a lot of feedback from the very people who would use the visit in CSC/Planetarium for the educational purposes. This part is an important barometer to check if the designer's idea is overlapping with the user's reception of the activity that is being developed.

In this point in time, idea for the workshop introduction has been to sell it as a product merged with a planetarium screening. Therefore, we set the times of the workshops to be carried out in the 1,5-hour intervals before the targeted screening, to allow school group to see the movie right after they end their workshop. At this stage it turned out that planetarium, seat-oriented, ticket system is poorly compatible with strict-count group additions to its sales operation. Therefore we have abandoned the idea of the merged workshop-screening ticket for school groups.

I.3.1 Cooperation between departments

This part of the process might only translate to rather large organizations. CSC employs about 300 people, and therefore its organizational structure can be challenging at times. In designing of the educational activity in the exhibition space, ESERO-Poland, which is a part of the Educational Lab, had to consult several specialists devoted to work in different departments of the organization. Below, specific tasks are listed, which needed to be carried out with help of employees from mentioned departments (marked with black circles on Fig. 3):

- Education Lab: Development of educational content for school groups,
- Planetarium Department: Connection of current planetarium cinematic content to the exhibits,
- Tickets and Information Department: Designing the screening-workshop-exhibits ticket interconnection,
- IT Department: Implementation of new product into the ticket sale system,
- Marketing and Sales Department: Calculation of the activity affordability,
- Operation Department: Involvement of explainers, exhibition area use for regular dates,
- PR Department: Promotion strategy for the activity.

Figure 3 – CSC organizational structure

Each of these interactions caused the proto-activity to evolve, and to adapt to organizations capabilities and needs, and therefore were crucial to the development process. It illustrates the need to reach for people of different background in the organization to possibly improve the output of one's work in development of new kinds of activities.

I.4 Second iteration

After the shift in direction, caused by the ticketing inconvenience in case of workshop-screening merging, workshops were to be a separate product, being sold like other extra-activities in CSC, i.e. lab activities, thematic evening for adults, etc.
Pilot version of the workshop was to be carried out 3 times a week for the most of the 2018 year, to evaluate its impacts and cost return in that timescale.
At this stage, activity was evaluated by the CSC Programme Committee, to see how its gains and costs balance each other institution-wise. To perform this evaluation, several scenarios were considered to have a wider view at the economic perspective of the product.
Important thing while performing calculations was to include all the work hours of people involved in the process of developing and managing the process of workshop introduction (these of continuous involvement in the activity, but also these who participate only at the beginning of the process). Another estimate to make was to include the exploitation of inventory like: flipchart holder, print-outs, markers, etc. These are presented as an example in Table 1.

Item	Gross cost
Scenario development	€ 690
Exploitation inventory (for one year)	€ 366
One-time worktime	€ 1 100
Continuous worktime (for one year)	€ 2 243
Sum	**€ 4 399**

Table 1 – Summary of cost estimates

After gathering the sum cost of the activity, it could be considered in light of specific number of workshops being carried out in said time, with particular come up (not every instance would be sold out possibly) and several levels of commission being imposed (Table 2).

Annual frequency		Annual income				Annual profit			
%	Resultant visitors	20% commission	30% commission	40% commission	84% commission	20% commission	30% commission	40% commission	84% commission
100%	2100	€ 4 540	€ 4 918	€ 5 296	€ 6 961	€ 757	€ 1 135	€ 1 513	€ 3 178
80%	1680	€ 3 632	€ 3 934	€ 4 237	€ 5 568	€ 605	€ 908	€ 1 211	€ 2 542
65%	1365	€ 2 951	€ 3 197	€ 3 442	€ 4 524	€ 492	€ 738	€ 984	€ 2 065
50%	1050	€ 2 270	€ 2 459	€ 2 648	€ 3 480	€ 378	€ 567	€ 757	€ 1 589

Table 2 – Profitability estimation based on visitor come up and commission levels

Above mentioned calculations were the base to the conclusion, that even though workshops would generate some profit, it was a far too low financial incentive to introduce the product to the customers/visitors.

I.5 Final iteration

After considering the economic calculation and abandoning the idea of commercialization of workshops, the idea of open access, downloadable resource for the teachers came to the forefront.
Basic idea of supplying teachers with guidelines how to use exhibits to discuss curricular topics, has been already developed at this stage. With the scenario of explainer-run workshop, work has been shifted to adapt it to be used by teacher guiding his/her class. This meant the exclusion of use of CSC inventory, like flipchart holder, and begged for much thorough explanations for the teacher, who do not have to be specialist in some issues being discussed in resource introduction segment.

Polish version of the final resource (Fig. 4) is available here: http://esero.kopernik.org.pl/warsztat/kosmiczna-lekcja-esero/

Resource has been published on CSC website, and can be downloaded by teachers interested in carrying out the lesson themselves, when they come to the planetarium with their students. As for now, download counter is showing 55 downloads, in the period of less than 3 months. This count is not disappointing, as it is rather niche among teachers to feel enough confident in unfamiliar environment to carry on with the lesson. Therefore, we feel that the final resource is deemed useful by the target audience.


Poland

esero

KOSMICZNA LEKCJA

95 minut

klasy 6–8 szkoły podstawowej, 1–2 szkoły średniej

astronautyka | obserwacja ziemi | technologia

www.esero.kopernik.org.pl

25 min. **Zwiedzanie wystawy**

Poproś uczniów, aby korzystając z eksponatów prezentowanych na wystawie „Patrz: Ziemia", zebrali informacje (w tym nazwy eksponatów) związane z zadanym tematem. Uczniowie mogą zwiedzać wystawę samodzielnie lub zespołowo. Mają na to zadanie 25 minut. Poproś ich o punktualność.

Poinformuj animatora obecnego na wystawie o prowadzonych przez siebie zajęciach. Uczniowie mogą korzystać z jego pomocy. W razie potrzeby sam/a możesz ich naprowadzić na eksponaty dotyczące konkretnego tematu.

10 min. **Przygotowanie wypowiedzi**

Po zakończeniu zwiedzenia wystawy poproś uczniów, aby w kontekście przydzielonego im tematu omówili w zespołach obejrzane eksponaty i opracowali wspólną wypowiedź.

25 min. **Prezentacje poszczególnych zespołów**

Poproś uczniów, by wszyscy razem zebrali się i aby każdy z zespołów po kolei zaprezentował wyniki swoich obserwacji (w tym własne logo). Na tym etapie nie przewidziane są dyskusje pomiędzy grupami czy uzupełnienia z Twojej strony. Pozwól uczniom się wypowiedzieć i wyartykułować własne wnioski.

Po zakończeniu wszystkich prezentacji wywołaj dyskusję na temat przedstawionych przez uczniów wyników. Poproś ich o podsumowanie swoich obserwacji, a następnie dodaj własne spostrzeżenia. Możesz ukierunkować dyskusję na temat korzyści płynących z eksploracji kosmosu lub na kwestię rozwoju technik i technologii kosmicznych oraz ich wpływu na codzienne życie ludzi, a przede wszystkim na multidyscyplinarność związanych z nimi badań. Możesz także poruszyć temat uczestnictwa w programach kosmicznych, które niekoniecznie wymaga przeszkolenia kosmonautycznego.

10 min. **Podsumowanie warsztatów**

Poproś, aby każdy zespół stworzył plakat, spisując zebrane informacje w kilku punktach na brystolu w formacie A1. Uczniowie mogą wykonać plakat na miejscu lub w klasie, po powrocie z planetarium.

Figure 4 – Cover and random page of the Space Lesson resource

II. CONCLUSIONS

Whole path of activity/resource development has been covered – from the analysis of the problem to be addressed, through several iterations of the solution, to the final one, which does not have to be very similar to the first, prototype one. This case shows that sometimes, while developing new resources or activities, we should look at the wider picture – be it a perspective of our institution, or of the visiting people. The final product presents rather uncommon way to involve teachers in the science centre or planetarium spaces – as a substitute for an explainer figure. This substitution is important for the activity impact, as it has the potential to temporary transform the relation expert-student into a tutor-student, which gives students much more creative interest in the surrounding, which in this case is the exhibition around the planetarium dome.

ACKNOWLEDGMENTS

Resources being discussed were developed by the ESERO-Poland office. ESERO-Poland programme is an European Space Agency educational programme being carried out in Poland by Copernicus Science Centre.

Fulldome Dronography

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BIOGRAPHIES

Pavel Karas is the Chief Program Coordinator and a fulldome creator at Brno Observatory and Planetarium, Czech Republic. His main interests are real-world photography, videography, and time-lapses. He also participates in live music events under the dome.

ABSTRACT

In this paper we will present the technologies which can be used for the aerial videography with focus on the fulldome production. We will share our good and bad experiences gained during the production of our recent fulldome show "Moravia 360" [1]. During last few years, drones have become a very popular, accessible and widely-used tool for video production. Even inexpensive non-professional models are equipped with advanced stabilization technology and a decent camera. Can they be used for the fulldome production?

INTRODUCTION

During last few years, drones have become a very popular, accessible and widely-used tool for video production. Even inexpensive non-professional models are equipped with advanced stabilization technology and a decent camera. In a classical widescreen format, aerial shots are very common nowadays. However, when it comes to the fulldome production, new challenges arise: the requirements for the resolution and the angle of view are not easy to be met, some parts of the drone constantly interfere with the field of view, etc. Finally, the camera stabilization and smoothness of the camera movements are much more challenging in a fulldome production than in a classical production.

Figure 1 – DJI Matrice 600, Panasonic GH4 and Sigma 4.5mm f/2.8 fisheye (photo courtesy: UpVision)

I. EQUIPMENT

I.1 Single Camera vs. Camera Rig

In a "conventional" fulldome videography, the lack of resolution is often resolved by building a so-called camera rig which usually consists of four, five or even more cameras. The shots from the individual cameras are subsequently synchronized and stitched together using a specialized software. There are two main drawbacks of this approach which lead us towards a single-camera solution: (1) A camera rig made of (semi)professional cameras is way too heavy for a conventional drone and the rigs made of light action cameras did not provide us with satisfactory results. (2) The video stitching works quite well only when a camera remains static. When the camera starts moving, the seams start to be visible. This problem cannot be solved using any conventional template-based stitching but might be overcame using advanced methods based on optical flow.

We prefer to use a single camera solution which is not only seamless but also much easier to process. The main drawback of this method is the vertical resolution limit which is 4K nowadays, but we find this resolution sufficient for many planetariums.

I.2 Diagonal vs. Circular Fisheye Lens

A circular fisheye lens provides 180° angle of view in all directions and is hence a perfect solution for a fulldome video. However, with aerial shots, one does not need such wide field of view all the time. A diagonal fisheye lens may be used instead, to cover the scene in front of the camera which is subsequently projected on the front side of the dome and blended with a sky which can be either recorded separately or created artificially.

I.3 Stabilization and Camera Movements

The perfect camera stabilization is essential. Typically, the drones are equipped with gimbals providing a decent stabilization, but they are not adapted to large and heavy fisheye lenses so a slight modification, tuning and/or additional custom weights are needed. Fast camera movements are usually to be avoided. Some of the camera orientations, typically a topshot (i.e. camera aiming down to the ground), look very unusual and unnatural in the dome so they must be used with care or the camera should move gradually into such a position so that audience can get prepared for it.

II. POSTPRODUCTION

In this section we describe a typical workflow of postproduction of drone videos:

1. Additional software stabilization if needed.
2. Manual masking of drone propellers and other parts which are not supposed to be in the final composition.
3. Manual fine-tuning of the field of view and camera orientation.
4. Blending the video with a pre-recorded or artificial sky.
5. Color grading and final postprocess.

III.SCREENSHOT EXAMPLES

Figure 2 – Front shots with a circular fisheye lens (Valtice Castle and Dukovany Power plant)

Figure 3 – Front shots with a diagonal fisheye lens (Blatnice church and Baťa Canal)

Figure 4 – Top shots with a circular fisheye lens (Macocha Abyss and Brno City)

IV. AUDIENCE FEEDBACK

Since the premiere, "Moravia 360" has had 16,000 viewers over four months of projection. Although most of the people enjoyed the show, we've also gathered constructive feedback, either personally or through our Facebook page. Firstly, most of the negative comments were due to lack of sharpness in some of the shots. According to our experience, sharpness was not limited by the camera resolution but rather by the sharpness of the circular fisheye lens used (Sigma DC 4.5mm f/2.8). We are therefore looking for a better lens. Secondly, there were a few comments to the (insufficient) smoothness of the movements. This could be improved by shooting in 60 fps – however our current equipment does not allow us to do so. Thirdly, some of the spectators felt dizzy during the projection and had to leave the dome. It seems that the fulldome effect combined with the effect of a flying camera is problematic for some people. We have to say, however, that the positive comments clearly outweighed and "Moravia 360" is one of our most successful shows.

ACKNOWLEDGMENTS

We would like to thank to companies UpVision and SkyPix for their equipment, knowledge and experience in the field of aerial videography, used during making of “Moravia 360”.

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Astronomy and Physics in Toys

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Galina Zhelezniak *Kharkiv Planetarium named by Yuri Gagarin*
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BIOGRAPHIES

Dr. Nataliya Kazachkova current activities are connected with creation of popular science shows for the primary and secondary school students.
Mrs.Galina Zhelezniak is a director of Gagarin Kharkiv Planetarium.
Mrs.Veronica Istomina is a research engineer and part time physics and astronomy teacher in Kharkiv Liceum № 89

ABSTRACT

Our work is dedicated by the creation of entertaining science shows for the primary and secondary school students (with common name Paradox Shows) which can be used during the science lectures at Planetariums, as so as summarizing lessons at the secondary schools. Closed collaboration between the lecturers of Planetariums, scientists as so as primary and secondary school teachers may create a brand of new possibilities for the Astronomy and Physics education. We will present a successful example of collaboration between Planetarium and other educational institutes.

INTRODUCTION

Active teaching process and learning come in a lot of formats nowadays and can help students with their understanding of complicated Physics and Astronomy theories and laws. How to deep the students' understanding and make the serious topics much easier for the audience. A planetarium can be a great educational tool for that. Using simple children toys and self-made demonstration we have developed some theme shows for the primary and secondary school students. It is well-known that appreciation of astronomy and physics beauty starts since the early school age (usually from 7-12). At ECYGDA (which is an NGO situated at Karazin Kharkiv National University) and Gagarin Planetarium STEM teachers together with planetarium lecturers have been working on a vocational physics course for primary and secondary school children since 2007. The main goal of the activities is to trigger a kids' motivation to do simple physics research projects, hands-on experiments and demonstrations beyond the school curriculum. During such kind of regular trainings pupils have the opportunity to obtain an insight into scientific methods of investigation, to conduct their own projects, and promoting their activities and simple investigations at the different events like Night of Science, Scientific Picnics, Science festivals etc.

I. SCIENCE SHOWS AS TEACHING TOOLS

I.1 Kharkiv Planetarium and its educational possibilities

Kharkiv Planetarium is a special astronomical centre combining the advantages of a theatre and an auditorium. Stars, Planets, Galaxies, Comets and the Sun are “actors” at that unusual theatre. Apparatus “Planetarium” situated at the Star Hall allows to watch at fascinating pictures of the Star Sky. It is possible to watch stars both at the Northern and the Southern hemispheres of the Earth on a Dome of our Star Hall. Eight Media Projectors create the effects of a Sunset, Polar Light, a meteoric shower, a panorama of Kharkiv or the Moon landscape covered with craters. With the help of modern digital media projectors it has become possible to demonstrate scientific films and beautiful photos of space objects in the Universe. There is also an observatory in our Planetarium where visitors can find a telescope allowed to observe stains on the Sun, the Moon surface, planets, bright comets and another space bodies. Popular science lectures (programmes) of the Planetarium are devoted to the different objects of the Universe and understandable for the visitors of the wide age range. Variety of theme lectures and science shows have been worked on and corresponding of the Official School curricular. Our young visitors can observe the beautiful star sky which is unforgettable for all of them! On the pictures below you can see the Star Hall (Fig.1) and a small lecture auditorium (Fig.2)

Figure 1 -- The Big Star Hall at the Planetarium

Figure 2 -- The Small Hall for the lectures

I.2 Science Shows in Kharkiv Planetarium and collaboration with ECYGDA and Kharkiv's schools

Kharkiv Planetarium and ECYGDA (Educational Centre of Youth Gifts Development) have agreements with 25 Secondary schools (and the Lyceum № 89 is among them), where science communicators from the Centre and lecturers from the Planetarium with the help of University students from the Faculty of Physics and Technology regularly demonstrate Physics Theme Shows, in a format of entertaining physics competitions related to the content of the Official School Physics and Astronomy Curriculum. During those shows the lecturers are able to select and choose the students who have capabilities for experimental work and invite them to join regular trainings at Kharkiv Planetarium. Those selected primary and secondary school students have regular (once a week) short theoretical lectures (45 or 60 min), giving by university teachers accompanied by practical training (90 min) led by university teachers or students.

II. ASTRONOMY AND PHYSICS IN TOYS AND SCIENCE TEACHING

There are lots of toys which can be used in Astronomy and Physics teaching. Here we present an educational show which has been developed in format of interactive science competition. Now the authors of the article have developed 8 different theme shows with common name "Paradox Show": Paradoxes of Magnetic Field, Wonderful Electricity, Paradoxes of Mechanic, Adventures in the Sound Land, Soap Bubble Show, Wonders under Low Temperatures etc. All the Shows have been created in collaboration between three organisations: Kharkiv Planetarium, ECYGDA (Educational Centre of Youth Gifts Development which is situated at Karazin Kharkiv National University) and Lyceum № 89.

Two industrial astronomy and physics toys will be described in the article. For example, so called The Astro Blaster (seismic accelerator) which dramatically demonstrate the Law of Conservation of Momentum for children to almost any age level. Drop it on a hard surface, then stand back as the top ball bounces to heights up to 5 times the original drop. The same thing happens when a supernova is created. The Astro-Blaster can also demonstrate what happens as a dying star collapses. The toy is shown at Figure 3. Another example of physics toy is a Drinking Bird (shown at Figure 4)

Figure 3-- The Astro Blaster

Figure 4 -- Drinking Bird is a famous science toy

The explanation of the motion of the second toy is not very simple for pupils. To pull off its famous trick, a drinking bird toy has to be contained a special chemical compound called methylene chloride. When stored inside the toy it looks like coloured liquid, but its properties are unique: It can transition easily from a liquid to a gas by essentially boiling at room temperature. Evaporated methylene chloride fills the bird's head while liquid methylene chloride fills the base of its body. Pressure differences caused by the condensing gas in the head encourage the liquid in the base to rise to the top of the toy, shifting the weight so its upper half topples forward into the glass in front of it. The liquid methylene chloride drains out in this new position and the balance of gas and liquid is restored. As long as the bird has a wet head or enough room-temperature water "to drink", the process of vaporization will cool the methylene chloride vapor and start the whole process over again.

One more example of the physics toy, which can be easily made by the students' hands is a Tornado Tube. It provides a hands on demonstration of "VORTEX ACTION". Tornados, whirlpools, waterspouts and similar motions in fluids that occur when liquid drops through an opening are called vortexes. The action is the concentration of kinetic energy (motion of the fluid). In the atmosphere, thermals and wind shear are the source of the energy which produces the vortex. In liquids, such as water, the potential energy (mass) is converted to kinetic energy as it descends, pulled by gravity through an opening. The resulting outward force tends to keep the liquid out of the exact centre, maintaining a "hole" in the remaining liquid. The demonstration can be seen at Figure 5.

Figure 5 -- Tornado in the plastic bottles

Lots of interesting demonstrations and toys for our shows had been designed and produced by the students some exhibits for the events which are organized in their schools. Some of them are Week of Physics, Science Picnic, Night of Science etc. The toys have been produced under the leadership of university students from the Department of Physics and Technology and research engineers from ECYGDA. They gain a lot from such practical trainings and their experimental skills are seriously improved by doing self-made experimental projects using recycled materials or simple household objects. In the pictures below you can see how the toys had been designing at the Physics room at Lyceum № 89.

Figure 6 -- A Toy from the household objects

Figure 7-- From the toy to the real research

Such informal teaching techniques has been well-known in lots of countries. Astronomy and physics are not the only topics that should be presented in planetariums. It is possible for the other subjects to be learned effectively under the Dome such as biology, chemistry or another STEM disciplines.

ACKNOWLEDGMENTS

The authors give lots of thanks to Prof. Dr. I. Girka and two very talented physics teachers from the secondary school "Obdarovanist" Oleksandr and Oleksandr Kamin for the aspiring guidance, invaluably constructive advices and understanding during work with school children. We also would like to give special thanks to Dr. Roman Starovoitov for his practical help and useful advices as so as an experimental support of the students. We also give special gratitude to the Director of Kharkiv Lyceum № 89 Kirychenko Svitlana for the financial support and organization during the students' trainings.

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The activity of Planetarium of Nagoya City Science Museum Japan

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BIOGRAPHIES

There are seven curators in our team. I graduated from Nagoya University graduate school of science in 1998. After joining Weathernews Inc. , I belonged to Nagoya City Science Museum in 2004.

ABSTRACT

The planetarium of the Nagoya City Science Museum has been opened on 1962. Through renovation of the Astronomy and Science & Technology Buildings, the new planetarium was opened in March, 2011. It was built replicate an actual starry sky as accurately as possible and with a diameter of 35 meters, it the world's largest dome. The theme of the planetarium changes every month. Topics such as seasonal stars and astronomy will be also presented. Approximately 500,000 visitors come every year.

INTRODUCTION

The planetarium of the Nagoya City Science Museum opened on November 3rd, 1962. We had been using a Model IV large-dome planetarium projection machine from Carl Zeiss since 1962. Until the closing on August 31st, 2010, the museum had been visited by more than 15 million people. Through renovation of the Astronomy and Science & Technology Buildings, the new planetarium was opened in March, 2011. The plan of the new planetarium is announced in the 2008 IPS(1). At the IPS 2014 Beijing, a post conference tour was held at Nagoya City Science Museum.

I. BASIC PLAN OF NEW PLANETARIUM

It is important for our visitors not only to enjoy planetarium show but also to look up at the real sky. So, Basic plan of new planetarium(2)
- Project stars as close to natural starry sky as possible on the largest 35m dome screen
- High quality immersive projection over the whole sky make us feel like traveling space
- Improve comfort by separated reclining seats
- Project astronomical events such as eclipse, meteor and aurora scientifically correct

The planetarium of Nagoya City Science Museum was certified as the "Largest planetarium" by Guinness World Records in 2011. It was built replicate an actual starry sky as accurately as possible and with a diameter of 35 meters. We desired to make it as large as possible to reduce distortion of the shape of the constellation or parallax of stars looked up from the seats.

Figure 1 – Appearance of Nagoya City Science Museum

The whole system was unified and installed by Konica Minolta Planetarium Co. Ltd. Images are projected by UNIVERSAEIUM Model IX(an optical planetarium : Carl Zeiss), SKYMAX DS II-R2(a digital planetarium), and Media Globe Panorama(panorama system). Many other companies are also involved, such as sound systems, lighting systems, laser systems, dome screens, and viewing chairs, etc.

Figure 2 – Nagoya Planetarium from inside

There are seven curators in our team. Our team performs live commentary and program production. As the speaker and the creator are the same, I think that the message will be better conveyed to the visitors. Our regular shows are 50-minute long and held 6 times a day. We will give easy explanations about comprehensive astronomical themes every month such as how to observe stars at night.

II. ACTIVITY CONDITION

We coverd a variety of topics surrounding astronomy and space each month.
- June 2017 : “60years of artificial satellites”
- July 2017 : “The vast expanse of the universe”
- August 2017 : “The eclipse across North America”
- September 2017 : “The myth of Delphinus”
- October 2017 : “The science of sunset glow”
- November 2017 : “Andromeda galaxy”
- December 2017 : “Want to see Aurora !”
- January 2017 : “The red full-moon”
- February 2018 : “Caught the gravitational waves”
- March 2018 : “Astronomy of the ancients”
- April 2018 : “The starry sky of the southern hemisphere”
- May 2018 : “Planet go around the sun”

The number of visitors in the previous dome was about 250,000, but since the new dome, the annual average is around 500,000.

ACKNOWLEDGMENTS

We appreciate having given me the opportunity to announce it at IPS. We would like to thank everyone involved in the construction and operation of the new planetarium.

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Planeterella: a science experiment becomes an educational tool

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BIOGRAPHY

Studies

- 1988 – 1992: Master in industrial engineering - biochemistry
- 1992 – 1993: Postgraduate in Environmental Sciences

Professional experience

- 2005 – present
  Head of communication and Science Communication - Planetarium of the Royal Observatory of Belgium
- 1995 - 2004
  Manager of Cultural Center De Maalbeek in Etterbeek (Brussels)

ABSTRACT

The Northern Lights are a natural and beautiful phenomenon. Since the beginning of time, people have tried to understand what causes the aurorae. Norwegian physicist Kristian Birkeland wanted to study this phenomenon and created an experiment where he could simulate auroral light: the planeterella.
The STCE (Solar Terrestrial Centre of excellence) has made their proper version of this experiment for scientific use and also one for educational use. The Planetarium of Brussels will receive this exemplar of the Planeterella and we will use it during our astronomy lessons for school children to explain the science behind the aurorae and give the children the chance to see the auroral lights themselves.

INTRODUCTION

Figure 1 – Outside view of the Planetarium in Brussels

The Planetarium of the Royal Observatory of Belgium is situated in the capital city Brussels, near the Atomium. Every year, more than 45.000 visitors experience here a magical discovery. This Planetarium is one of the oldest (inauguration in 1935 during the Brussels International Exposition) and one of the largest planetaria in Europe (23 metres diameter dome with 350 seats).

The Planetarium of the Royal Observatory of Belgium has many strengths: educational, cultural, tourist and as a national heritage. With a new dynamic, the Planetarium is committed to constantly adapt and innovate its offer, for both schools and the general public in the form of new shows and permanent and temporary exhibitions.
In 2009, the International Year of Astronomy, the planetarium acquired a new 'digital' system thanks to the significant support of the Federal Minister of Science Policy, the National Lottery and the National Bank of Belgium.
The public is welcomed to a completely reconfigured projection hall, with a projection system made up of 8 state-of-the-art video projectors covering the entire dome of 23 metres in diameter. The spectator will be immersed in an image projected on the entire surface area of the 840 m2 dome. Furthermore, thanks to a database of astronomy images with more than 100.000 stars, it's possible to voyage between the planets and to fly over their surfaces.

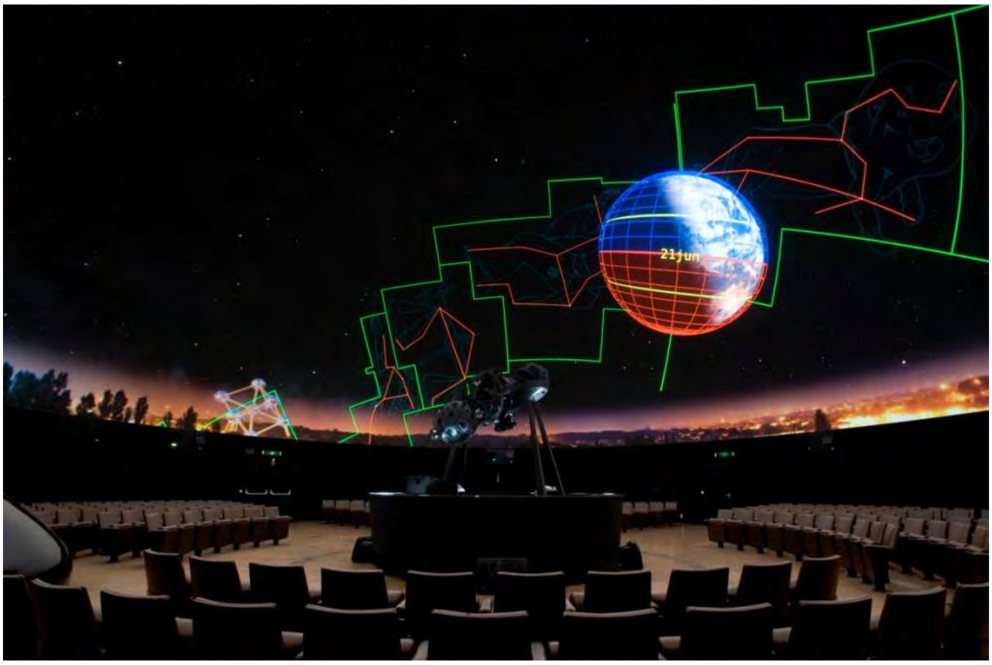

Figure 2 – 23m dome with digital projection (RSA system with 8 Barco Sim 7 projectors)

I. CONCEPTION OF A PLANETERRELLA

I.1 Terella, invention of Kristian Birkeland

The Northern Lights are a natural and beautiful phenomenon. Since the beginning of time, people have tried to understand what causes the aurorae. Only about hundred years ago Norwegian physicist Kristian Birkeland came with the hypothesis that the aurorae are created by charged particles from the Sun travelling along the Earth's magnetic field lines and exciting our atmosphere. Birkeland wanted to study this phenomenon and in 1901 he created an experiment where he could simulate auroral light: the Terella.

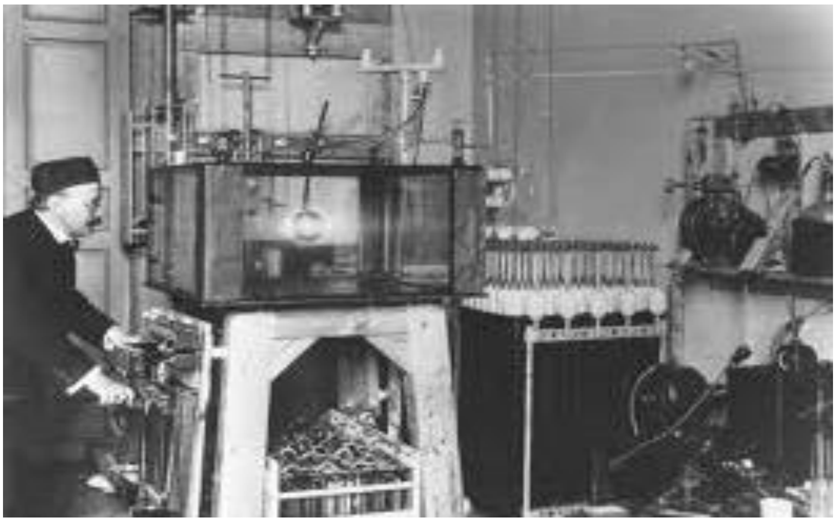

Figure 3 – Kristian Birkeland with his Terella

I.2 Planeterella by Lilensten

A Planeterrella as a polar light simulator, after the invention of Birkeland, was first initiated by Prof. Jean Lilensten (CNRS) at the Institute of Planetology and Astrophysics in Grenoble (France). It simulates the Sun's atmosphere or corona and the aurora phenomenon thanks to magnetic spheres inside a small vacuum chamber.
It was at first conceived as an instrument for scientific experimentation. Scientists wanted to use this instrument for two phenomena's: the study of the solar atmosphere or corona and a simulator of auroras.

Figure 4 – Planeterella

II. TECHNICAL DETAILS

II.1 Technical explanation of the Planeterella instrument

The instrument consists of 3 metal objects – 2 round spheres: one big and one small and one metal needle - that are put under a glass bell jar.

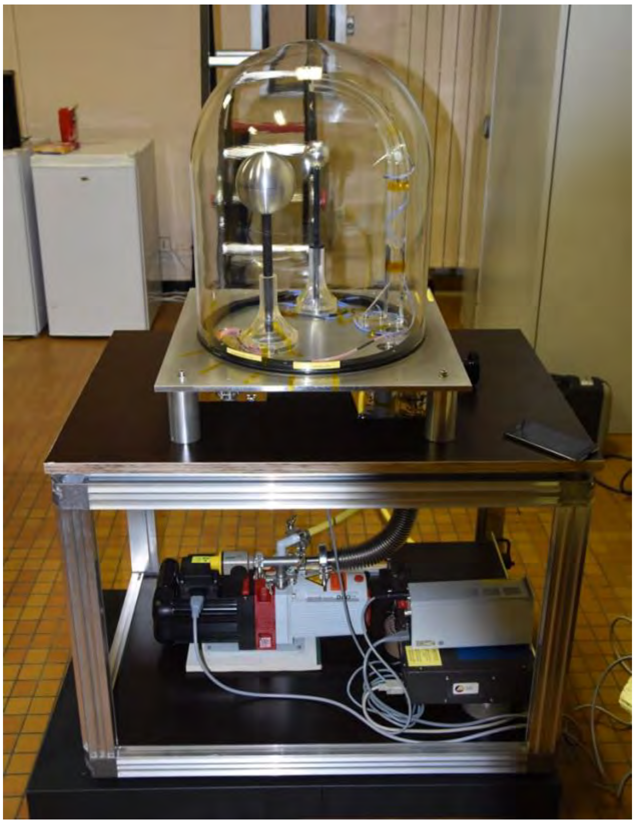

Figure 5 – Total view of the Planeterella instrument

This glass bell jar is made vacuum with a pump, we arrive at a stage of almost vacuum: only some few air molecules are left in the vacuum bell jar, this means the same situation as we have in outer space.
Inside both of the round spheres are magnets.

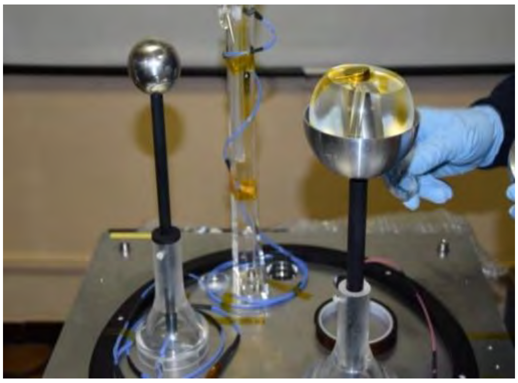

Figure 6 – Two round spheres with magnets inside

In the large sphere, the magnet is slightly tilted with an angle of 11° compared to the vertical axis, to simulate the inclination of the Earth. The orientation of the small sphere is less important, as the magnet is aligned with the axis that holds it (i.e. vertically). The magnet in the large sphere should be directed, as perfectly as possible, in the direction of the little sphere.
There's also a third component present: a cathode, that is fixed on the same height as the equator of the big sphere.
The cathode and the big sphere are connected to the electrical circuit and we create a voltage difference between them so that negatively charged electrons will move from the cathode to the anode.

II.2 How works our Planeterella ?

The Planeterella can be used in different settings.
The simplest setting is the one where you can demonstrate the relation between Earth and the Sun.

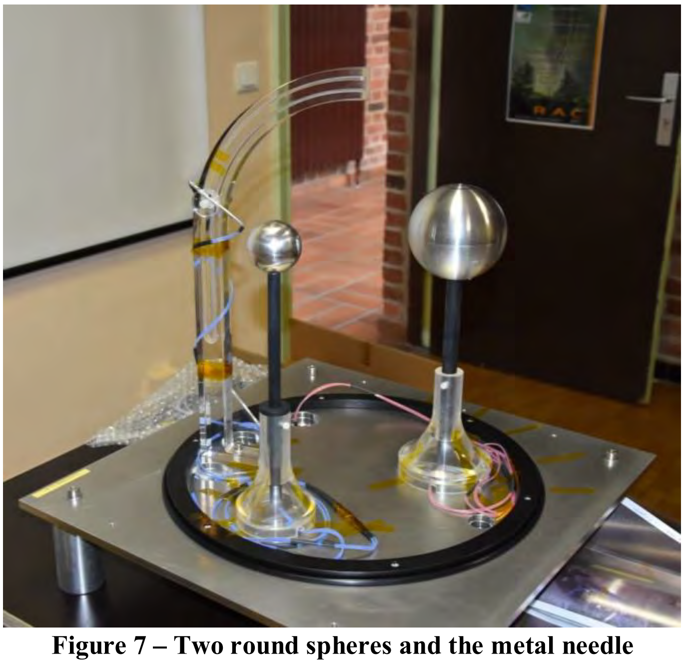

Figure 7 – Two round spheres and the metal needle

The cathode is the Sun who emits charged electrons to the big sphere, who represents the Earth, the electrons on their way to Earth collide with the few molecules present in outer space and they emit light while discharging. This process creates an overall present light purple glow in the bell jar, this is the representation of the Sun's corona.
Some electrons continue their way and arrive at Earth where they follow the geometry of the magnetic field lines of our Earth's magnetosphere (simulated by the magnet in the big sphere).
This way Earth's magnetic field is made visible and at the same time you see the concentration of light at the poles, or the auroras on Earth.

There's also a second possible experiment: the small sphere can also be used as cathode, but that creates so much light (like the bands of Saturn) that the visitors don't look at the aurora on Earth anymore.

II.3 What can be explained thanks to the Planeterella?

It is very didactic, as it can be used to explain auroral light production as well as various other astrophysical phenomena. Apart from auroral lights, the device simulates quantity of interactions between stars and planets: Uranus and Neptune with their tilted axes, the interaction between Ganym de and Jupiter, stellar jets and rings and even the interaction between a magnetized extrasolar planet and a close star.

Figure 8 – Planeterella in action with the overall present light purple glow, this is the representation of the Sun's corona.

III. PLANETERELLA AS AN EDUCATIONAL TOOL

III.1 Why using a Planeterrella in a planetarium or science centre?

The STCE (Solar Terrestrial Centre of excellence) has made their proper version of this experiment for scientific use and also one for educational use.
The Planetarium of Brussels will receive this exemplar of the Planeterella and we will use it during our astronomy lessons for school children to explain the science behind the aurorae and give the children the possibility to see the auroral lights.

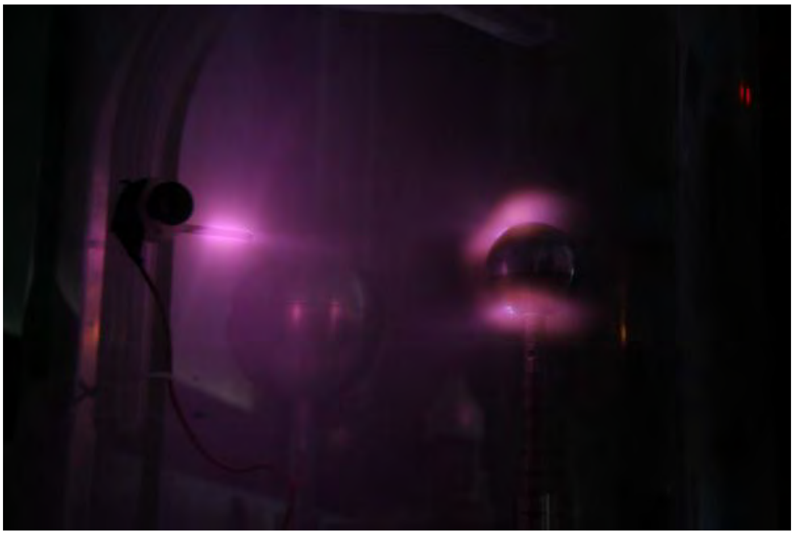

Figure 9 – Planeterella in action with the visualization of the auroras on Earth

The experiment is attractive and fascinating for the public: in a dark environment they observe the Planeterella, they see a light purple glow under the glass bell jar and also a more intense glow around the big sphere.

It is very didactic in the way that an image says more than a 1000 words, the public 'see' the science happening, which makes them curious, so they are keen to listen to the explanation. Adults as well as children are fascinated and for most educators it's no problem to adapt their explanation to the level of the public.

It is inspiring in the way that visitors know they are looking at an instrument that's used for experimentation and scientific research, it's like they look over the shoulder of the scientist and they are part of the experiment.
For children, this is very positive, you can walk them through the explanation using the scientific method: observe, ask questions, formulating a theory and testing of the theory.

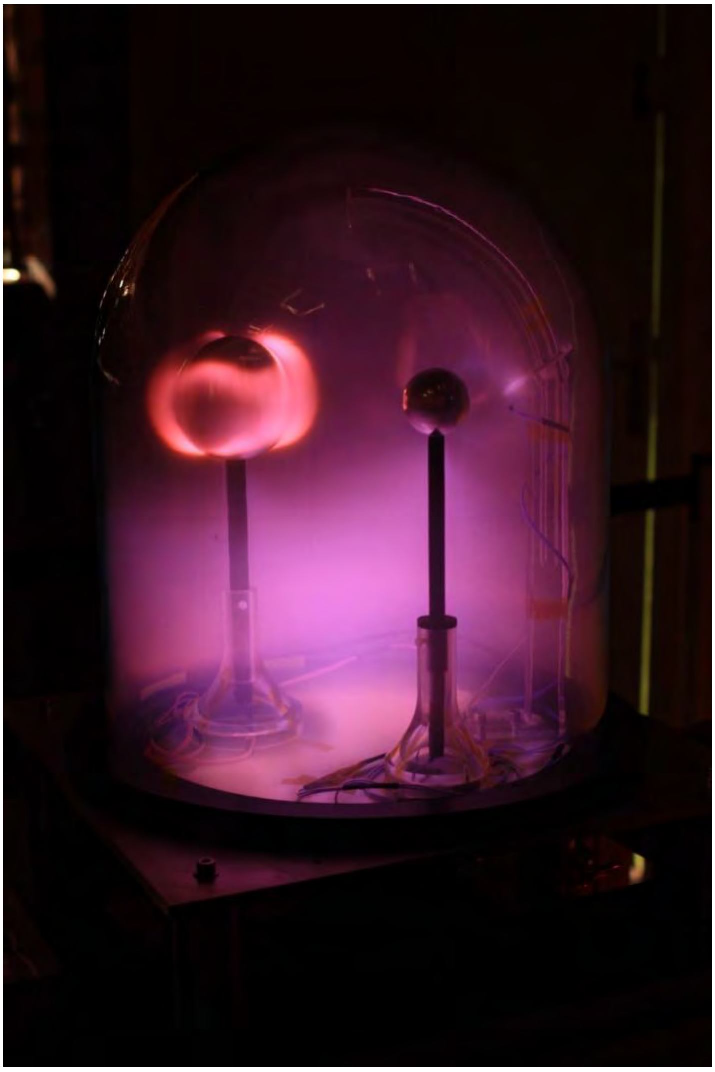

Figure 10 – Planeterella in action with the visualization of the Earth's magnetic field

IV. THE PLANETERELLA IN BRUSSELS

IV.1 First experiences with the Planeterella

Difficulties and solutions:

- several hours to one day is needed to reach the correct level of vacuum
  - we would like to keep the planeterella continuously in vacuum
- the room should be darkened
  - our idea is to use it in the dome
- the device makes some noise
- security measures: high voltage
  - build wooden panels around the lower part of the device (vacuum pump and electric generator are hidden and the noise is lowered)
- the spheres cannot be moved
  - make them mobile via a magnet

Figure 11 – Demonstration of the Planeterella in a class room

It's clear that the use of the Planeterella as a science instrument is not so obvious, but since the experience for the public is so positive we are motivated to continue and to find solutions for these inconveniences.

IV.2 Future

An enhanced version (less noise, better vacuum maintenance, portable system) is currently elaborated by the Royal Belgian Institute for Space Aeronomy (www.aeronomy.be). This prototype will be installed and used in the dome of the Planetarium of the Royal Observatory of Belgium in order to be tested with school audiences.

ACKNOWLEDGMENTS

The Planetarium of the Royal Observatory of Belgium wants to thank:

- BISA, Royal Belgian Institute of Space Aeronomy
  Karolien Lefever, Eddy Equeter, Claudio Queirolo and Eddy Neefs

- STCE, Solar Terrestrial Centre of Excellence Petra Vanlommel
  The Solar-Terrestrial Centre of Excellence (STCE) is a scientific project which aims at the creation of an international expert centre and the valorization of Solar and Solar-Terrestrial research and services. The STCE clusters the know-how of 3 Belgian Federal institutes:
    - Royal Observatory of Belgium (ROB)
    - Royal Meteorological Institute (RMI)
    - Belgian Royal Institute for Space Aeronomy (BIRA-IASB)

REFERENCES

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- BISA, Royal Belgian Institute of Space Aeronomy: pictures and information of technical assemblage
  www.aeronomy.be

To Tell a Story

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BIOGRAPHY

Toshi Komatsu is Director of the Fujitsu Planetarium at De Anza College. Prior to that, he spent 18 years at the Planetarium at the Lawrence Hall of Science, presenting and developing live, interactive shows. He has an A.B. in Physics and Astrophysics from the University of California, Berkeley.

ABSTRACT

Can just anyone tell a story (in the planetarium)? Why and when should you use stories in your programs? How do we stay focused on what is really important? I share a template for summarizing any story using the "rule of three"—the Word, the Sentence, and the Paragraph. People respond naturally to the framework of a story, and including elements of drama and knowing your audience are key components of any good story to effectively connect to and teach your audiences. Co-panelists Patty Seaton and April Whitt will expand on these concepts with examples.

INTRODUCTION

As planetarians, we may not think of ourselves as storytellers, but we are. As science communicators, we need to actively engage the public, and one of the best tools is storytelling. Over the millennia, humans have been conditioned to tell and to listen to stories. Story is a familiar format, and framing science into a story gives a way to package it into a comfortable medium for our audiences. However, while any story *can* be told, we all know not every story is told *well*.

I. CONNECT WITH STORY

My interest in applying storytelling to the planetarium began when I read *Connection: Hollywood Storytelling Meets Critical Thinking*, by Olson, et al. The book lays out three templates as the framework for telling compelling stories. These templates can be applied to any story—from my family trip to Europe to the mysteries of dark matter.

The key is to make a connection with your audiences to make them more receptive to learning. All good stories have a common structure that help them flow—a structure that has been refined through the ages. If you can format your story in familiar package for people, it will be much easier for them to follow you. This is especially important the more complex and abstract the topic, as is the tendency with science and astronomical concepts.

One basic rule is the rule of three. We eat breakfast, lunch, and dinner. We order Tall, Grande, or Venti. Three is a number of completion, and there are three story templates: the Word, the Sentence, and the Paragraph. These templates are very specific in form, but also very flexible in practice. When used together, they can help you focus your story.

II. THE WORD

The "Word" is a template to summarize your entire story into a single word. This is an exercise to focus your story and grab the attention of your audience. It should encapsulate not only your theme, but why anyone should care.

To help, *Connection* explains a theory of storytelling with two axes. The horizontal axis is your narrative structure, or the flow—the beginning, middle, and end. The vertical axis measures a story's approachability. As science communicators, we often stay in the head, making presentations too cerebral and filled with jargon. It is more effective when speaking with the public to be lower on that axis, communicating from the heart or the gut. We must remember when we are talking with the public, we cannot use the same language we use with our colleagues.

It’s okay to have emotions. People relate to emotions. Of course we want to be scientifically accurate, but we need to excite the public and spark inspiration. Although science must be done objectively, we should be passionate when we communicate that science.

Consider the larger, human context for your story. Make your next show not about “exoplanets,” but about “possibilities.” Focus not on “constellations,” but on “imagination.” Present not about “gravitational waves,” but “triumph.”

III. THE SENTENCE

Next, we have the “Sentence.” This template defines the conflict, because a story doesn’t begin until something happens. Think about the last time you saw a boring movie or TV show or planetarium show. You were probably thinking, when is something going to happen? The conflict does not have to be physical; it can be a challenge on the road to discovery, but there has to be a reason for the story.

The Sentence is also referred to as the “And, But, Therefore” model because of its structure. Start with some information AND add more information BUT then something happens, THEREFORE a solution is found. In defining the conflict, this template begins to define the flow of your story.

Here is an example of a famous story, told badly:

> Once upon a time, there were three bears AND they made some porridge AND they thought it was too hot AND they went for a walk AND a little girl appeared AND she knocked on the door AND…

There is a lot of information, but nothing is happening. This is more of a list than a story. Too often, science stories get stuck in an AND, AND, AND pattern. We collected data, and we collected more data, and we analyzed the data, and we concluded “X.” This has plenty of information, but no flow. It jumps from information to conclusion, but there was no conflict or challenge.

Compare with this version:

> Once upon a time, there were three bears AND they went for a walk, BUT an evil little girl broke into their home—eating their food and destroying their furniture—THEREFORE they chased her away to save their home.

In this case, there is a clear conflict—the vicious girl who terrorizes the poor, innocent bear family. It is what makes the story interesting.

So, for your next exoplanet show, consider:

> We have long wondered about other life in the Universe AND whether or not we are alone BUT we needed to know if planets are common or rare, THEREFORE the Kepler Mission was designed to take a statistical survey of stars.

Science is defined by the questions it asks, and those questions make for excellent sources of conflict for stories.

IV. THE PARAGRAPH

The “Paragraph” expands on the Sentence, giving additional detail to the story’s flow. It outlines one of the most common story frameworks—the Hero’s Journey—composed of these nine parts. You can fill in the blanks with the details of your story.

> IN AN ORDINARY WORLD…
> A FLAWED PROTAGONIST gets their life upended when
> A CATALYTIC EVENT HAPPENS.
> After TAKING STOCK,
> THE HERO COMMITS TO ACTION.
> But when THE STAKES GET RAISED,
> THE HERO MUST LEARN THE LESSON in order
> TO STOP THE ANTAGONIST, so the hero can
> ACHIEVE THEIR GOAL.

Think of your stereotypical movie trailer narration. It begins with, "In an ordinary world…" It sets up the world or the state of the world. The protagonist is flawed, because the story should show them improving or learning. This could be a scientist in pursuit of a solution. A "catalytic event" is the thing that gets things started, and upsets the current world order. "Taking stock" is the protagonist's assessment of how the world has changed, and then they take "action." But (notice there is a "but" built in), then the main conflict is introduced, the thing that the hero must learn or discover or that allows the hero to grow. The antagonist does not necessarily have to be a person, but it could be the problem itself.

Here is another famous story, formatted in this template:

> In a time of galactic civil war, on a quiet farm, an impatient young man gets his life upended when he finds a message from a kidnapped Princess, and meets an Old Man who tells him about "The Force." After his family is murdered, the young man hires a cocky space pilot to help him rescue the Princess and aid the Rebel Alliance. But when the Princess' home planet is destroyed and the young man is drawn into the enemy's battle station, he must learn how to use "The Force" in order to destroy the enemy, so he can save the Princess and the Rebel Alliance.

With exoplanets, the journey may be the challenge of collecting precise measurements to find planets. With the Higgs-Boson, it may be the struggle to get that 5σ level of confirmation. Whatever it is, let the audience come along on the journey of scientific discovery.

Here is one more tip for storytelling. Mathematically and with your head, $2 + 2 > 4$ makes no sense. But from the gut, it means do not give your audience "4," give them "2 + 2." Make the audience think, and let them guess what comes next. They will be far more engaged if they have to work out "2 + 2," rather than just being told "4."

V. SCIENCE STORIES IN THE DOME

Keep in mind what domes are best at showing. We can show stunning, immersive visuals. Flat images are beautiful, but many of us can also show fulldome models. We also can visualize big data. Charts and graphs are terrible for the public, so make them into a story. Break them down, and tell the story of the data, not just points on a graph. And we can use our domes as time machines. Where else except in a planetarium do you have full mastery over space and time? We can go backwards or forwards, a few hours, or billions of years. Half our storytelling work is done with the tools we already have available because planetarians can not only tell, we can show.

So, what is your story? How will you tell it? I hope you will keep in mind these three templates. The Word—make a connection. The Sentence—and, but, therefore; introduce a conflict and make something happen. And the Paragraph—take your audiences on a journey of discovery.

ACKNOWLEDGMENTS

Thanks to my co-presenters, Patty Seaton and April Whitt.

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Olson, R., Barton, D., Palermo, B. (2013). *Connection: Hollywood Storytelling Meets Critical Thinking*. Los Angeles, CA: Prairie Starfish Productions. ISBN-978-0615872384.

Making high resolution VR video/time-lapse

O-Chul Kwon, Astrophotographer & Fulldome filmmaker
Email: kwon572@gmail.com

BIOGRAPHIES

O-Chul Kwon is a Astrophotographer & Fulldome filmmaker of Korea. Member of TWAN (The World At Night, www.twanight.org). Made <Aurora : Lights of Wonder (2016, 29min)> and won Janus Astro Awards at 11th Fulldome Festival (Jena Germany, 2017). Recently made <American West (2018, 8min)>, 8K x 8K time-lapse short film for planetarium.

ABSTRACT

For making high resolution VR video/time-lapse, you need many cameras and fisheye lens set. Let me introduce my rigs for some planetarium/VR projects. I used 1~5 camera sets for each situation.

INTRODUCTION

There are more and more needs for high resolution contents in our planetarium field. 4K is common and now 8K planetarium is made. In 2017, 8K full sphere theater was built in South Korea.

I have been photographing astronomical objects for over 20 years. This session introduces the process of making such high resolution contents about Aurora, Milky way or etc for planetarium. I will show my 4 rigs with 1~5 cameras to make up to 12K time-lapse or 8K real-time video.

I. WITH 1 CAMERA

Nowadays there are high-resolution digital cameras, such as Sony A7R3 / Nikon D850 / Canon 5Ds in market. Using these 8K resolution cameras, you can make 5K × 5K resolution fulldome images with just 1 camera and fisheye lens.

You can make 5K x 5K time-lapse movie. But if you want real-time movie, you cannot get even 2K × 2K resolution. At movie mode, the resolution is 3840 × 2160px or 1920 × 1080px, but there is no fisheye lens which matches the cropped field of view. General 8mm fisheye lens make cropped image. Entaniya 5mm fisheye lens make smaller image.

For more high-resolution, you need more cameras.

Figure 1 – 1 camera set

II. FOR TIME-LAPSE

For 360 VR, generally 3 camera-fisheye lens sets needed. Entaniya fisheye lens have 250/200 degrees FOV, so with these lens 2 sets are good. I used 3 8K cameras and could get about 12K 360 VR time-lapse. For perfect 360 images you have to shoot bottom image separately and composite later.

Figure 2 – 3 camera sets

For Fulldome format, it is half sphere, so only 2 camera set needed. I modified camera lens adapter for axis shift.

Figure 2 – 2 camera sets

This set can be used only for planetarium project.

III. FOR REAL-TIME VIDEO

If you want high-resolution real-time video. You need many camera sets. Because each camera can make only 2K or 4K movie at movie mode.

This is my rig for real-time aurora project. I used 5 Sony A7s cameras and 15mm full frame fisheye lenses. Common rigs have only 1 camera for upward. but for planetarium, upward is main direction, so I use 2 sets for upwards. For planetarium only then you do not need bottom image. If your project is for also VR, you have to shoot bottom image separately and composite later.

Figure 3 – 5 camera sets

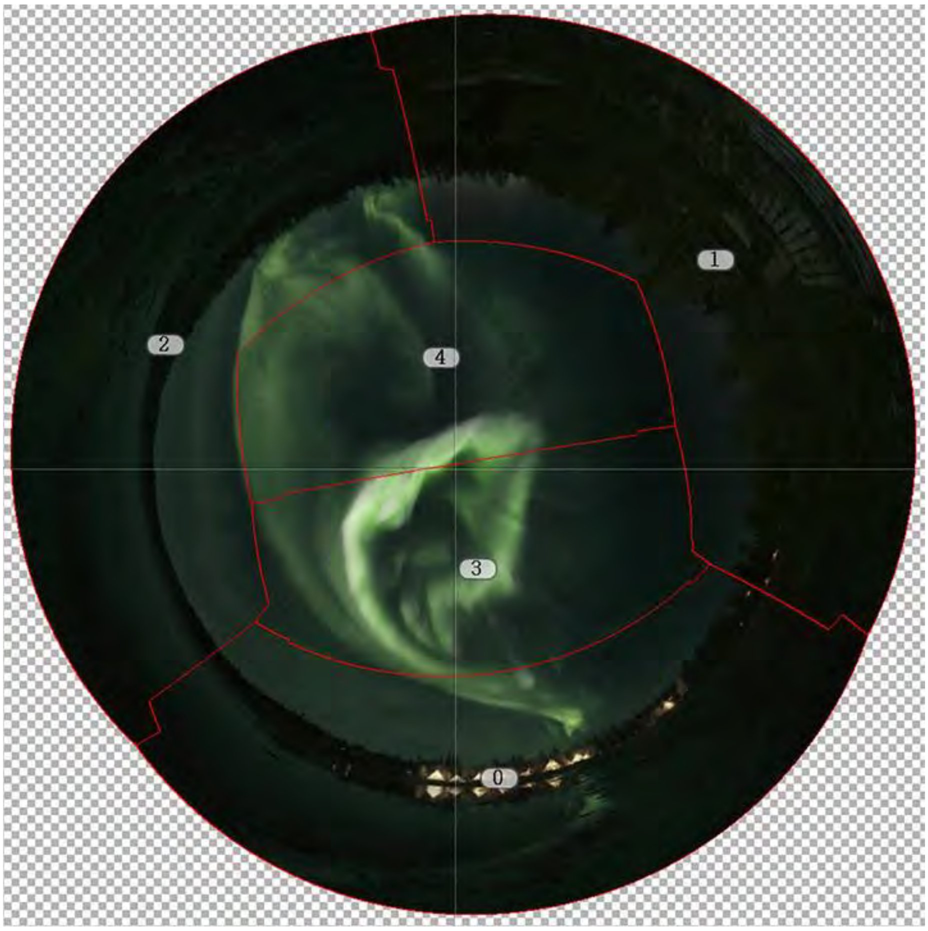

Figure 4 – stitched process for 5 camera sets

ACKNOWLEDGMENTS

You can see my high resolution project at :
www.aurorawonder.com
www.vimeo.com/kwonochul

REFERENCES

(-)

Two planetariums, one fab lab, one exoplanet

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Christelle Barclay, Cyril Birnbaum, Thierry Dassé, Caroline Turré
Email : firstname.lastname@universcience.fr

BIOGRAPHIES

Cité des sciences et de l'industrie (CSI)

Cyril Birnbaum: Director of the Planetarium
After graduating in astrophysics and space technology at Meudon Observatory, Cyril Birnbaum joined the CSI in 1998.
He held the positions of mediator and then deputy director of the Directorate of Scientific Mediation and Education. Since 2012, he has been the Director of the Planetarium.

Christelle Barclay: Production manager
Thierry Dassé: FabLab manager
Caroline Turré: International Affairs officer

Rio Tinto Alcan Planetarium

Etienne Laurence: Activities coordinator

As a biologist, Etienne Laurence is quickly interested in scientific vulgarization. Since 2013, he holds the position of activities coordinator at the Rio Tinto Alcan Planetarium. In addition to developing the programme of activities, he ensures the production of shows, manages the staffing as well as the daily operational requirements.

ABSTRACT

"Mission exoplanète" is a collaboration between the *Cité des sciences et de l'industrie_CSI,* one of the two « Universcience » sites with the *Palais de la découverte,* (Paris) and the Rio Tinto Alcan Planetarium of *Espace pour la vie* (Montreal). This project has two components: a three-month technical challenge and a program of visits exchange of know-how.

"Mission exoplanète" was selected by the France-Canada Agreement coordinated by the French Ministries of Culture/ Higher Education, Research and Innovation, and the Department of Canadian Heritage. This program fosters lasting links through the sharing of best practices, the implementation of joint projects between museum institutions in Canada and France.

I. THE CHALLENGE

I.1 The approach

The main focus is a reflection on our practices in the field of the science communication.
How scientific popularization projects with complex subjects, as astronomy, can be designed by FabLabs tools and approach?

The starting point of this project was a "maker" challenge.

A Paris team was selected following a call for projects "Mission ExoTerre" (Earth-like planet mission) launched by the FabLab manager, Thierry Dassé.
A Montreal team was coordinated by Etienne Laurence from the Rio Tinto Alcan Planetarium in collaboration with *the Société des amis du Planétarium de Montréal*.

After they agreed to select the exoplanet Kepler 442b, both teams worked for 3 months without exchanging their respective data.

While the first team was building a model of the Kepler 442b exoplanet's surface, the second one was prototyping a rover able to explore the exoplanet.

Since K442b is supposed to be rocky and it is located in a zone believed to be "habitable" where liquid water might exist, the rover was equipped with six drive wheels, 7 precise and powerful motors, temperature and pressure sensors, a gyroscope ... And it was built to be water-resistant!

The mock-up of the planet was made using mainly polystyrene, plaster, sand, glue and paint. The design is a team work based on the known data and… a little imagination.

Figure 1-A few team members in Paris

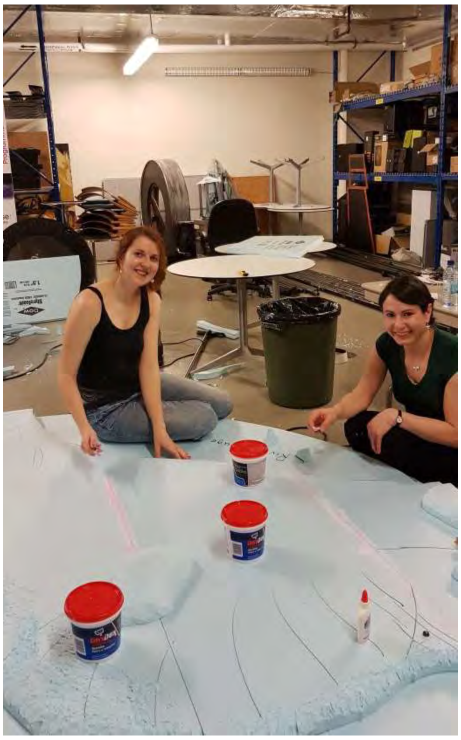

Figure 2A few team members in Montreal

I.2 The Landing

The highlight of this technical challenge was an event held on April 7: the landing of the rover.
The robot was brought to Montreal by Thierry Dassé.

Paris audience attended the live landing simulation thanks to the duplex from Montreal.

Figure 3-The rover on the surface

Some videos of interviews and the planet approach of the rover were simultaneously sent to Paris as in real space missions.

But how could we communicate about this event in the context of refuting science?

As scientific institutions, it was very important for us not to contribute to *fake news*.

Thus, the publicity about this project and the event were cautious and the communication was voluntary imprecise while arousing curiosity (for example, we used the expression "come and attend an experience of landing" instead of "come and attend a landing").

Scientific guarantees were given by a series of conferences on exoplanets all the event long with astronomy experts including Jean-Pierre Lebreton, the scientific and technical manager of the Cassini-Huygens mission.

Figure 4-Jean-Pierre Lebreton

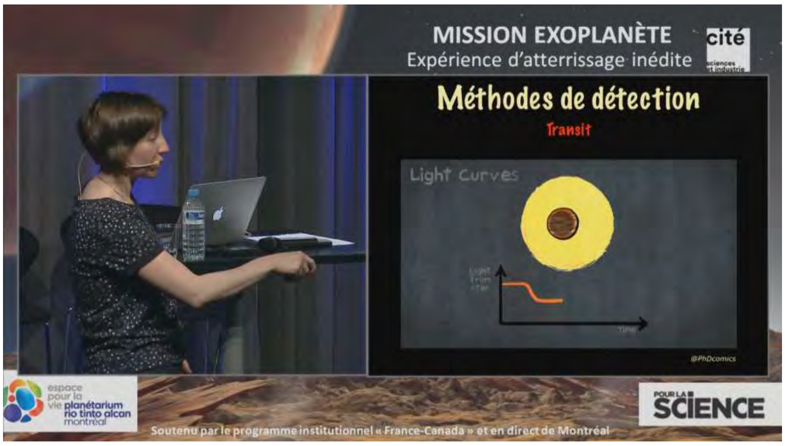

Figure 5-Emeline Bolmont

Sebastien Carassou, an astrophysicist and video maker on Youtube, was also in charge of providing clues about the feasibility of such an expedition:

- Is it possible to reach such a distant planet? (1000 light-years away)?
- What speed is required?
- What are the limits according to the laws of physics?
- ...

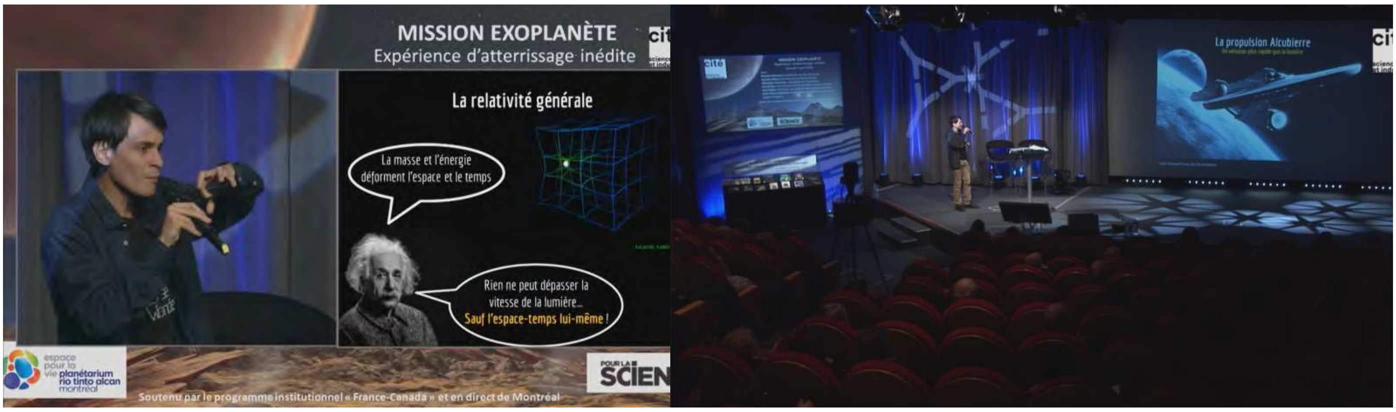

Figure 6-Sébastien Carassou

This last conference and the zoom-out on the models closed this amazing evening.
It was a great opportunity to question the audience about false information they may receive…

II. SHARING BEST PRACTICES

II.1 An opportunity to exchange

The event on 7 April was the first time the teams had gathered and the first time they discovered the models they worked on. The event was also the first step of the program of visits and in-depth exchanges, prepared by Caroline Turré and Etienne Laurence.

They could exchange about their questions they had and the problems they encountered.

It was also the beginning of a the week of visits, workshops and exchanges of know-how, which allowed to better know the partners from Quebec involved in science communication.

Program of vistits

In Quebec for the Paris team (4 people)

- Espace pour la vie: Feedback and outcomes of "Mission Exoplanète", Renovation projects of both Insectarium and Biodome
- EchoFab (Quebec)
- Science Center of Montreal: Fabrik/DIY area (Montreal);
- Demonstration Centre in physics: Cégep Garneau (Quebec);
- Musée de la civilisation (Quebec)
- La SAT (Montréal)

After this IPS, our colleagues from Montreal will come to Paris (5 people)

- Cité des sciences et de l'industrie : Exhibition Department, Education Department, Planetarium, FabLab…
- Palais de la Découverte
- The National Museum of Natural History of Paris: Exhibition "Meteorites", Citizen science projects "Vigie Ciel" and "Fripon"
- Paris Observatory
- French Association Astronomy
- « Ciel & Espace » magazine

II.2 Project follow-up

Following this collaboration, we intend to develop and enhance networking mode with our colleagues and the other museum institutions.

We hope that this project and its approach could be re-used and improved: the plans, the documentation, the budget will be available in open access.

This collaboration showed us that it isn't necessary in cultural projects for all participants to be in the same place, in the same country.
We could imagine an event with a huge surface model where several rovers from different FabLabs in the world could land on.

The information below could make you to consider a similar project.

Model of K442b

Structure
Ø = 9ft (275 cm)
Made of expanded polystyrene, plaster, sand and rocks, on a plywood base
Layer of paint : acrylic
Model design inspired and leaded by Emiline Fillion
Panorama : image from a previous show on the satellite Io (credit : Sophie DesRosiers)
Total cost : 1000 CAD ~ 650 € (including 500 CAD for the panorama and its printing)
Three sessions over 3 weeks and 1 day of installation and touch-up

The Rover

Structure: freely inspired by RHex from Boston Dynamics and a species of sea turtle
Few raw material thanks to 3D-printing : 50€ / raw material: PLA (plastic made from corn starch)
Four hours printing for each wheel
Total cost: 1500 € (mainly for motors) ~1150$
The rover is built to be upgradeable.

Some characteristics of the rover couldn't be validated: does it work like an all-terrain vehicle? Can it resist to water? Four wheels could be enough? Can we use fewer motors?

To be continued...

ACKNOWLEDGEMENTS

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Pierre Lacombe (Planetarium Rio Tinto Alcan former Director)
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Société d'astronomie du Planétarium de Montréal (Alain Vézina)
Emiline Fillion alias Emiline of Avonlea
Patrick Geoffroy, Simon Gauthier, Mathieu Forcier, Patrick Cournoyer (technicians)

Cité des sciences et de l'industrie

Lisa Faye, Sabine Hug (Conferences program expert)
François Bisbal, Omar Bousselat

REFERENCES

- You can find further information related to the rover on the website http://mission-exoterre.gitlab.io/
- The Youtube Channel of Emiline Fillion : https://bit.ly/2sPC3Rl
- The Youtube Channel of Sebastien Carassou : https://bit.ly/1HOGdH7
- http://www.cite-sciences.fr/en/home/
- http://espacepourlavie.ca/planetarium

Terrain Maps and GIS Data on the Planets in the Planetarium Dome

Raphaël LERBOUR, *RSA Cosmos*
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BIOGRAPHY

Raphaël Lerbour is a software engineer with 10-year experience in real-time computer graphics development. After a PhD about streaming and adaptive rendering of large terrains, he has had the opportunity to continue working with digital terrains at RSA Cosmos, bringing high resolution data from probes and satellites to planetariums.

ABSTRACT

Although the planetarium is historically dedicated to looking up at the sky and exploring space, digital technologies also offer the freedom to look down to Earth and land on other bodies of the Solar System. The scientific community uses satellites, probes and land surveys to produce an ever-growing public collection of high resolution imagery, elevation maps and other georeferenced data. We would like to raise awareness on how producers and animators can use those planetary data in a planetarium, even during interactive sessions. We will show real-world examples, explain the technical basics, and point out the best resources.

INTRODUCTION

First, we will explain what terrain maps and GIS data are, and where to find them. Next, we will present how high resolution terrain maps are used in planetarium software for realistic 3D navigation on the surface of the planets. Finally, we will share some resources and advice for importing, producing or importing new GIS data yourself, using dedicated tools.

I. TERRAIN AND GIS DATA

Geographical Information Systems (GIS) is a very general term. As the name suggests, GIS data can be any information related to geography, or the surface of planetary bodies. Here, we will talk about how such data can be displayed on virtual planets in planetariums, by projecting the information on the 3D surface at the correct coordinates. As this usually requires replacing or overlaying the terrain with the data to display, we will then indistinctly use the terms *GIS* and *terrain*. Furthermore, terrain maps like satellite imagery and digital elevation models represent a large portion of available GIS data.

In this section, we will present various kinds of terrain data, and show where some of them can be obtained.

I.1 Types of Data

Terrain data can be classified in several broad categories, each with its own applications.

Purpose: Terrain can be *realistic* for general high quality 3D navigation (eg. satellite imagery), or *illustrative* for showing specific information (eg. the distribution of people on the globe). See Figure 1 for examples.

Storage: Terrain datasets can be stored as *raster* data (images with pixels, eg. for photography), or *vector* data (lines and polygons, eg. to show geographical areas and their borders). Raster data is more common and usually higher resolution, and it is required for realistic terrain, but it can get very large. See Figure 1 for examples.

Nature: Terrain raster is usually *imagery* ("colors" in various wavelengths), or *elevation* from a reference ellipsoid like sea level on Earth (for 2D storage of 3D surface geometry). See Figure 2 for examples. Various other information can be used, especially for illustrative purposes. However, in most cases those need conversion as imagery, typically using fake colors.

Extent: Terrain can provided as a *global* map, or cover only a smaller, *local* portion of the surface. Local datasets must be georeferenced (using metadata such as their coordinates) or they will not show at the right position and/or size on the planet.

Figure 1 – Realistic raster image (left) vs Illustrative vector image (right). Left: Blue Marble from NASA (BMNG July 2004). Right: age of continents and oceans from IPGP.

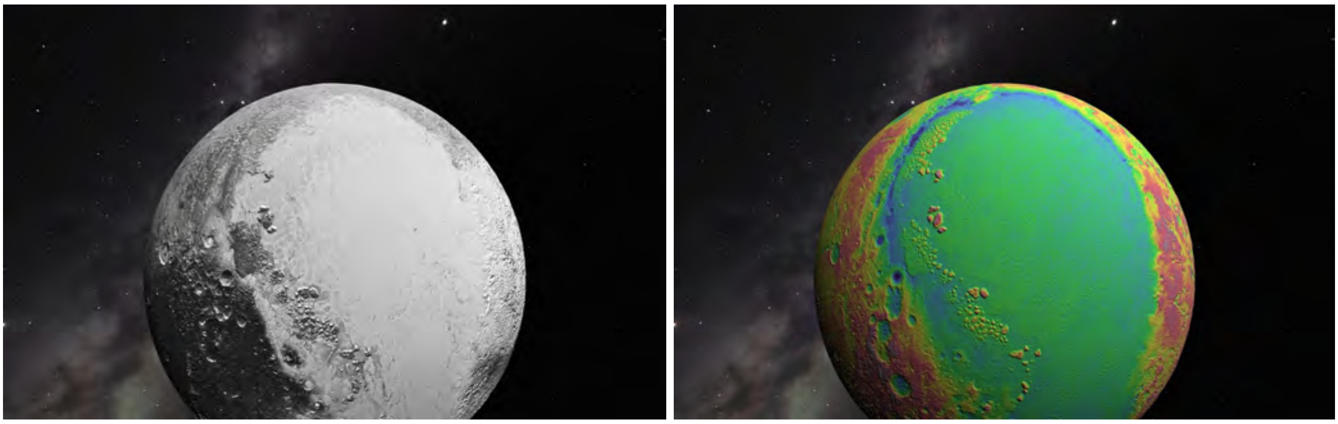

Figure 2 – Photography (left, grayscale) vs Elevation with topography shading (right). Pluto data from New Horizons.

I.2 Sources for Earth

There exists an incredible amount of GIS data for areas all over the world and beyond. Here we will list the resources we used for the images in our figures, mostly high-resolution terrain used for realistic 3D navigation.

Global Earth satellite data can be both freely obtained from public organizations like space agencies (NASA, ESA…) or purchased from private companies (Airbus, DigitalGlobe…). See Figure 3 for examples.

Those sources are generally disparate, and their data are often provided as raw records that require expert processing to become usable in contexts other than research. Companies like PlanetObserver fill that gap by selecting, merging and processing data from various sources to improve quality (natural colors, less clouds and artifacts…), ensure global image uniformity (seamless mosaic) and regularly update critical areas (like emerging cities), all in a ready-to-use presentation.

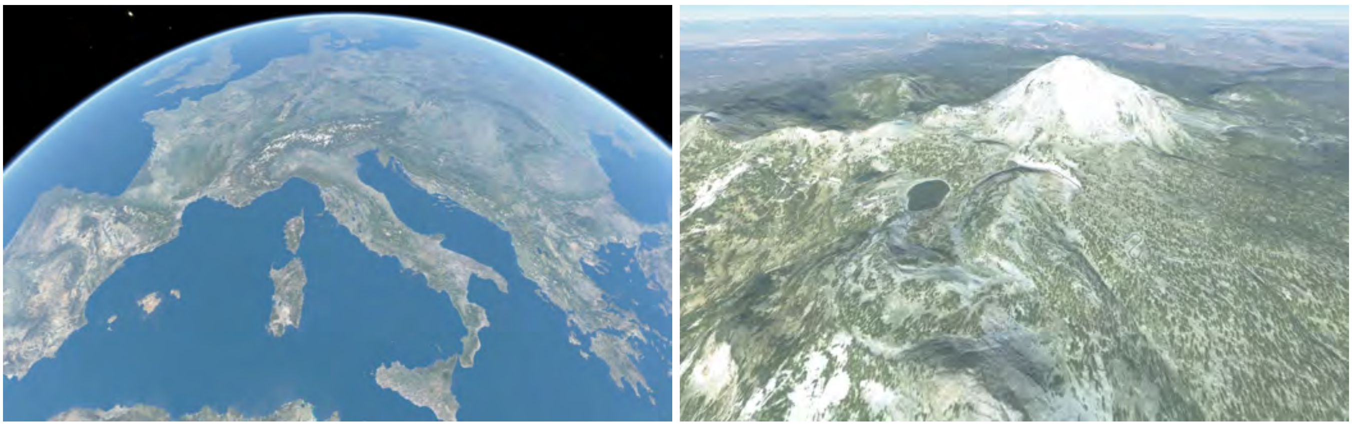

Figure 3 – Satellite photography from PlanetObserver (PlanetSAT). Left: global 15m/px dataset using Landsat 7 and 8 sources. Right: local 2.5m/px dataset of Lassen Peak (California) using Spot Image source.

In addition, national and regional geography institutes often offer aerial photography and/or DEMs (*Digital Elevation Models*) from geological surveys. See Figure 4 for examples. Here are some online resources:

- USGS for USA: earthexplorer.usgs.gov
- IGN for France: professionnels.ign.fr/donnees

Figure 4 – Aerial photography from local sources. Left: Brest Métropole (France) at 0.1m/px. Right: Yellowstone National Park from NAIP (USA) at 1m/px.

I.3 Sources for the Solar System

For bodies other than the Earth, the only original sources are probes from space agencies (mostly NASA) and their partners. In some cases, at the end of missions, the result can be directly used as global terrain data. See Figures 2 and 5 for examples.

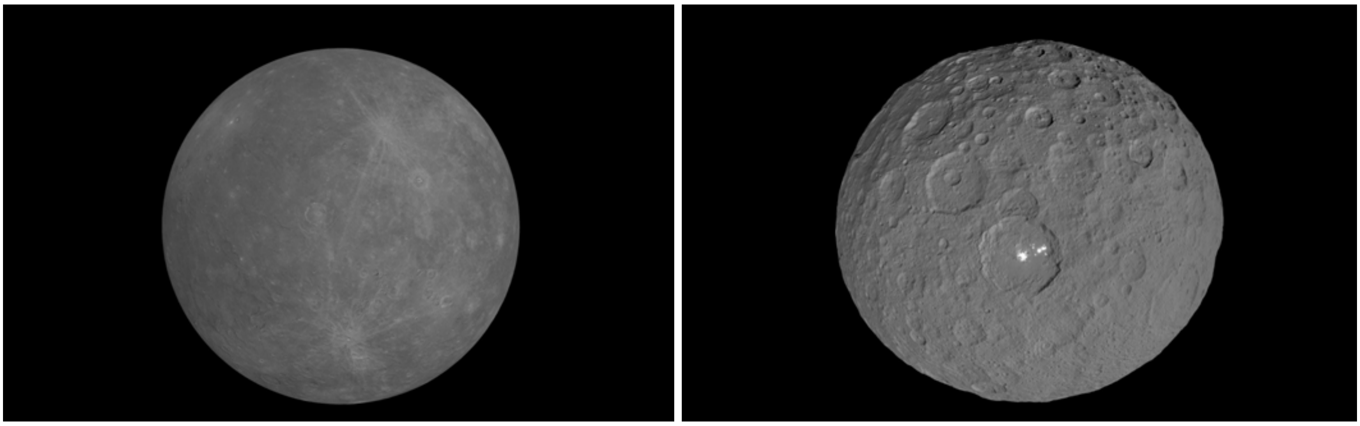

Figure 5 – Recent high resolution datasets from NASA space probes. Left: Mercury from MESSENGER. Right: Ceres from DAWN. See also figure 2 for Pluto from New Horizons.

However, like for the Earth, we prefer sources that gather and process global data to make high quality, ready-to-use maps:

- USGS Astropedia is an incredible resource for global maps as finished products, especially when the original source is hard to obtain or process: astrogeology.usgs.gov. They also sometimes improve on the originals by merging data from various sources, as can be seen on Figure 6.
- For ongoing missions like Juno, amateurs are usually the first to produce nice looking and usable results from raw records. They can be found at unmannedspaceflight.com and planetary.org. See Figure 7 for examples of their work.

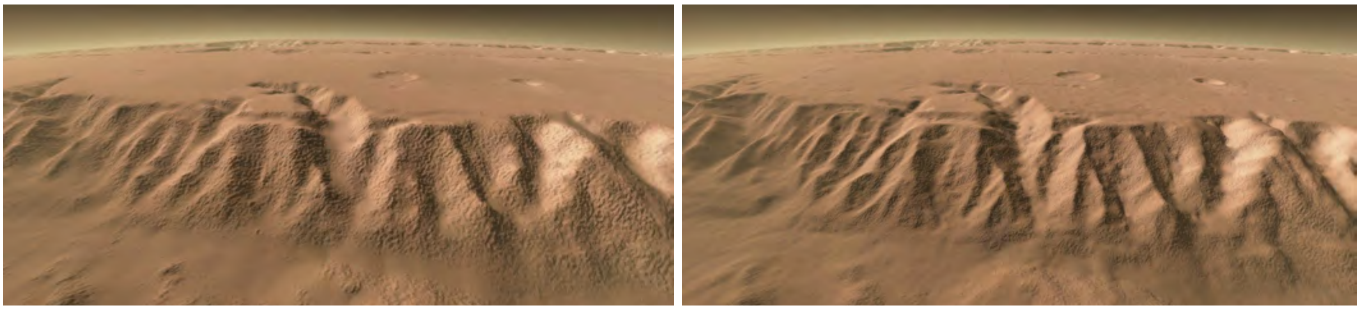

Figure 6 – Recent improvement to Mars elevation from USGS. Left: global 460m/px MOLA data from 2001. Right: MOLA blended with local 50m/px HRSC data (on half of planet's surface) for a global map at a compromise 200m/px.

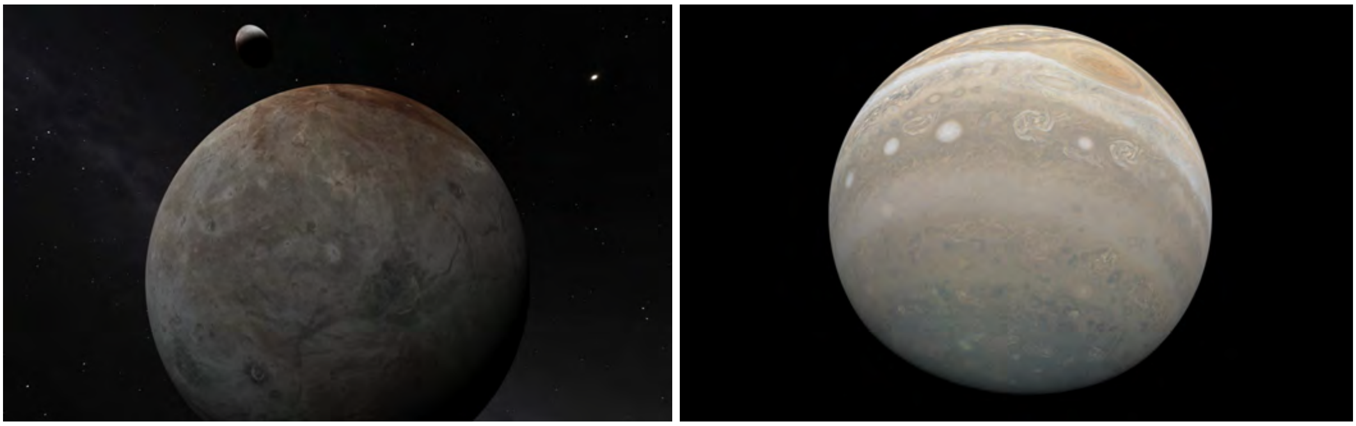

Figure 7 – Recent color maps from a community of enthusiasts. Left: Pluto and Charon by John van Vliet, data from New Horizons. Right: Jupiter by Björn Jónsson, data from Juno (polar areas) and Cassini (equatorial areas).

Finally, ongoing orbiter missions release very high resolution local imagery and elevation on a regular basis, for example:

- HiRISE from Mars Reconnaissance Orbiter: uahirise.org/catalog/ (example result can be seen in Figure 11)
- LROC NAC from Lunar Reconnaissance Orbiter: wms.lroc.asu.edu/lroc

II. CLASSICAL USE IN PLANETARIUMS

In this section, we will explain how terrain data are handled by real-time planetarium simulators to allow realistic 3D navigation on the surface of the planets. We will then show examples of applications that require no effort to use in planetarium shows: it's what we do so you don't have to.

II.1 Real-Time Technology

Terrain datasets can be huge. In the case of high-resolution global maps reaching well over several gigabytes, it becomes impossible to load and display all of the data at once. To enable real-time rendering at 60 frames per second and still get great quality, some compromises need to be made, and preprocessing is required. Here we will describe the basis of the approach used in my PhD thesis as well as by the technology I currently use, called Proland.

Maps are subdivided in a multi-resolution fashion using a quadtree. This allows to progressively load and selectively render only what is needed. The subset of used data is constantly adapting to the current viewpoint, in order to get the best resolution where it counts, as illustrated on the left part of Figure 8. Those structures and algorithms are usually designed for square 2D maps (like in video games), so they require a projection to handle entire planets and their curvature.

The equirectangular projection is the most commonly found. It is easy to use as it maps longitude and latitude directly onto the X and Y axes, but it produces high distortion and redundancy towards the poles. For real-time rendering applications we, like many others, prefer gnomonic projection on a cube (shown on the right part of Figure 8). That projection offers relatively low distortion, fast math, and friendly squares.

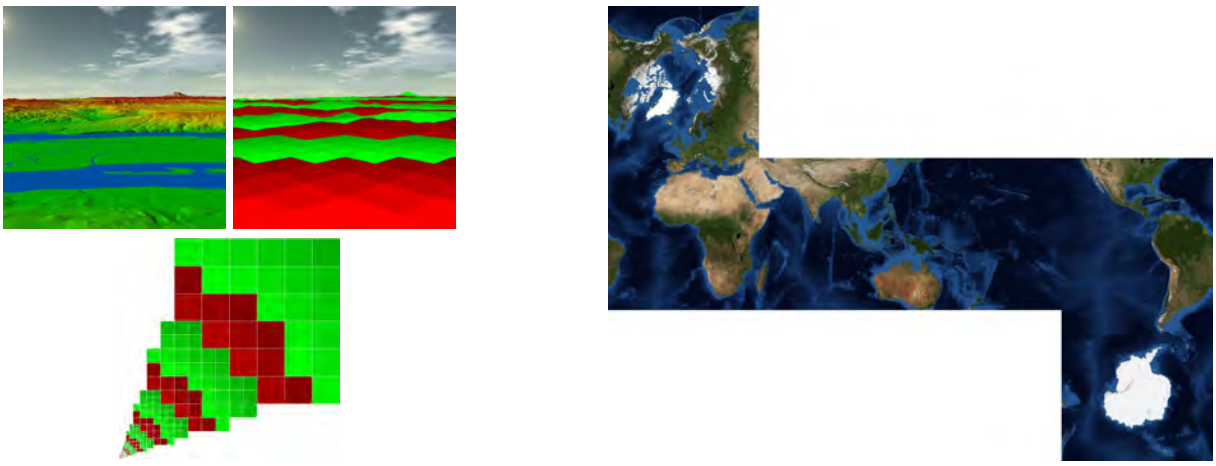

Figure 8 – Terrain rendering technology. Left: quadtree (multi-resolution) map subdivision for progressive loading and adaptive rendering based on viewpoint. Right: cube map projection.

II.2 Global Maps

Planetarium software distributions provide complete global maps, using their simulator's native file format and projection to ensure the best rendering speeds. Those maps are loaded automatically when the viewpoint gets close to the terrain, and they include elevation data, as they are intended for high quality 3D navigation. Figure 9 demonstrates some of those global maps. Sometimes multiple maps are available, from various sources, so you can choose the one that best matches your needs or your taste. New maps get added and others are improved regularly, as new data become available from geospatial sources.

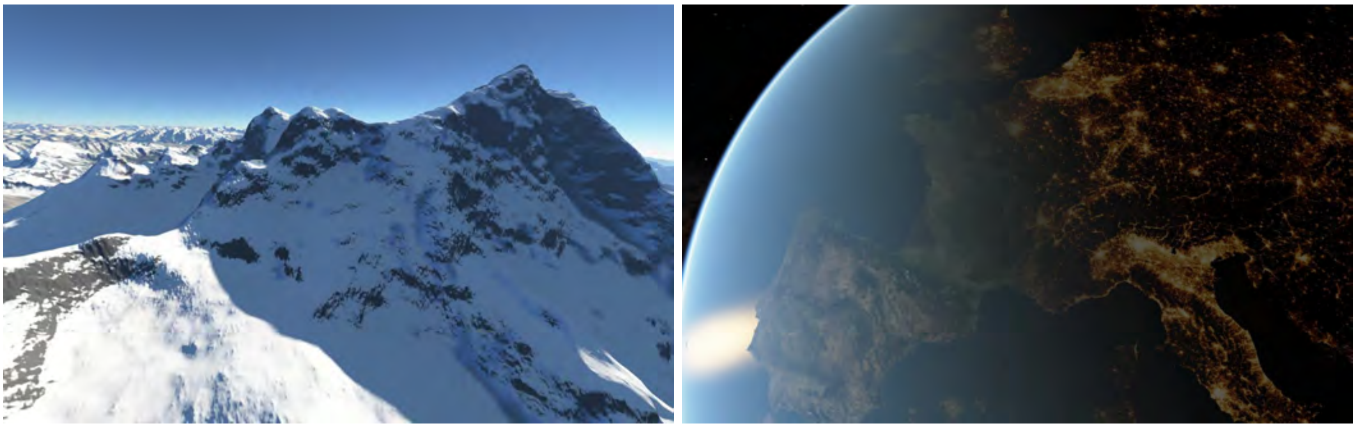

Figure 9 – Examples of data included in vendor distributions. Left: global 15m/px imagery (PlanetSAT: Landsat) and 30m/px elevation (PlanetDEM: SRTM + ASTER), also used to compute Earth's dynamic terrain shadows and cliff effect. Right: additional maps for night lights (VIIRS) and water mask for reflections (MODIS).

II.3 On-demand Patch Integration

Patches of terrain with higher local resolution can be added on areas of interest. Some examples may already be included in vendor distributions. However if you have a specific request, vendors may also offer services for integrating new patches. You can give the source data, or the vendor can use their contacts to find them for you. Then, the dataset will get processed to the native format and projection of their simulator, and finally installed in the planetarium. Figures 10 and 11 show some very high resolution terrain patches that were imported this way.

Figure 10 – The Cité de l'Espace (Toulouse, France) at various levels of precision. Left: global map (PlanetSAT) at 15m/px. Middle left: IGN national survey at 5m/px (free version). Middle right: IGN at 0.5m/px. Right: Toulouse Métropole at 0.1m/px.

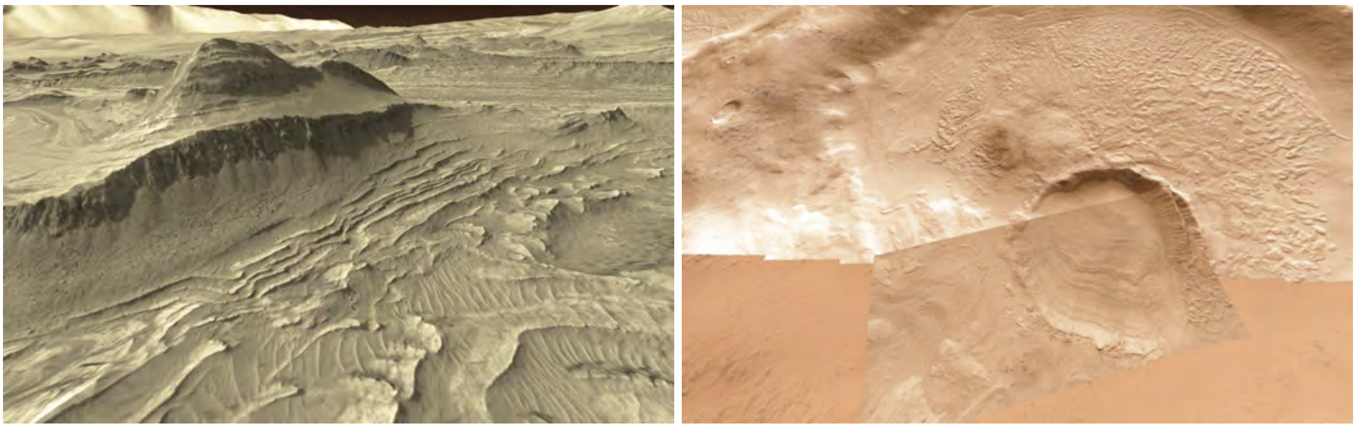

Figure 11 – Example patches on Mars. Left: Layered Rocks (HiRISE: imagery + elevation). Right: Crater Within Crater (composited from THEMIS + HiRISE for Mission to Mars demo by Jim Sweitzer).

III. DO IT YOURSELF

Just like you can add images and videos to your planetarium shows, it is also possible to add GIS data on your own. Any 2D dataset with coordinates can be added on the surface of the planets. However, this often requires processing data yourself, to make them look as you want and to ensure they are correctly displayed in the simulator. In this section, we will give you some tools and advice to help you begin that journey.

III.1 Tools You Can Use

First, you need to get terrain data one way or another. You can download an existing dataset from the web, use WMS (Web Map Service) or an equivalent protocol to stream a map on-the-fly over the network, or produce your own dataset from raw data or from scratch using dedicated GIS tools. Such tools are very diverse, and can also be used to adjust or troubleshoot the result. Here are some of the most popular:

- ArcGIS or ERDAS Imagine (general, commercial),
- GRASS or QGIS (general, free),
- ISIS (from USGS, for space probe data),
- Google Earth (mainstream, KML format),
- GDAL (powerful command-line tools and library).

When your dataset is ready, you need to export it in a format and projection supported by the software of the planetarium. If it uses GDAL as a back-end, any standard format and projection will work: the simulator will load and process the data on-the-fly for rendering. This is slower than using the simulator's native format, but it is much more versatile.

Finally, you can use the simulator to load your datasets, configure patch compositions, and fine tune the result to your needs. For example, you may want to exaggerate the elevation, or adjust the colorimetry to match that of another dataset such as the background. Example applications are shown in Figures 12 and 13.

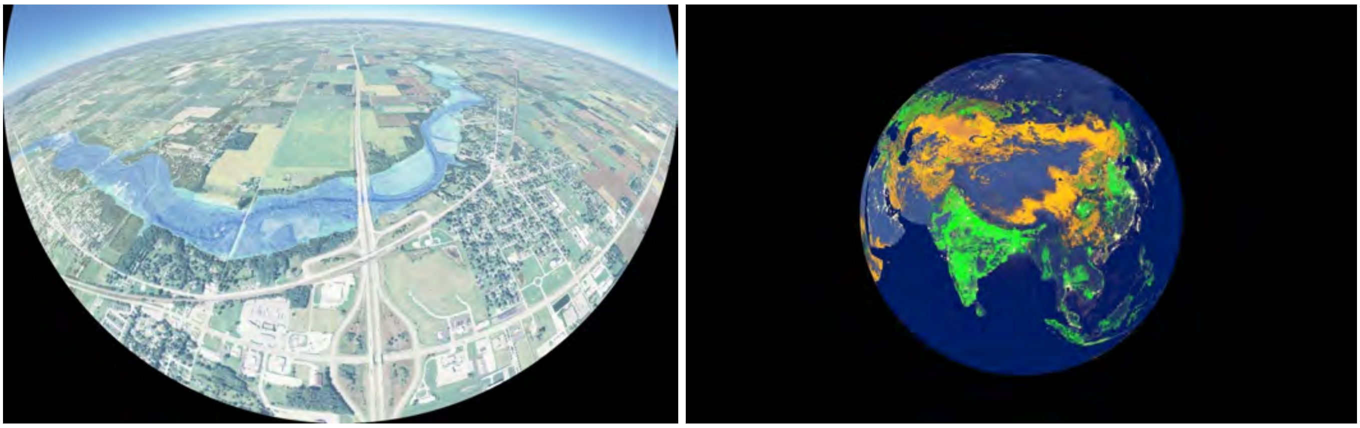

Figure 12 – Example compositions. Left: 15m/px PlanetSAT global map + 1m/px NAIP local aerial photo + translucent overlay simulating a water reservoir project (Ball State University of Muncie, Indiana). Right: Black Marble global map + crop land (green) + pasture land (orange) (California Academy of Sciences, data from earthstat.org).

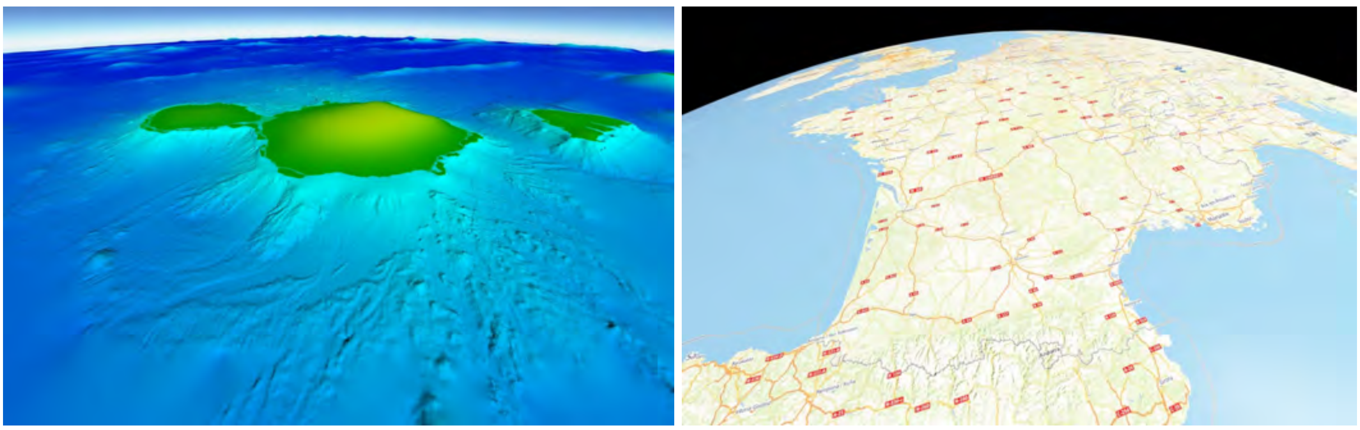

Figure 13 – Left: Tahiti seafloor elevation data (IPGP), topography shading and lighting are computed dynamically from elevation. Right: WMS dataset of OpenStreetMap global road network, streamed live from online server.

III.2 Terminology

To be productive while handling GIS data, you need to understand how it works. Even simple raster images require special care to be correctly manipulated and displayed, which can become head-scratching otherwise. We will thus conclude with a short introduction to some terms often encountered while working with GIS data and tools, in the hope of demystifying them.

Mosaic: Large maps often come as a collection of smaller files that tile to form a mosaic, for example using 1 arc-minute subdivisions. Those mosaics can be assembled using GIS tools to form a single dataset.

Metadata: Any GIS dataset requires metadata to be correctly handled by software. Those can be embedded in the same file as the dataset, using GIS-specific formats like GeoTIFF. Metadata can also come in accompanying "sidecar" files like WLD or VRT, if the dataset uses a more classic image format like JPEG or PNG.

Georeferencing: This is the most important metadata that must come with GIS datasets. It contains information about the dataset's projection, reference ellipsoid, bounds and resolution. Georeferencing is required for correct positioning of the dataset on the globe, and it can be adjusted using GIS tools. A useful list of spatial references can be found at spatialreference.org.

Nodata: This metadata is a special value used to identify pixels contained within the dataset's area but with no valid data. Those pixels will not get displayed, instead such areas will use the background global dataset. Dedicated alpha channels are less error-prone (and allow for partial transparency), but nodata is much more common.

Band: Also called channel or component. Most common datasets are 1-band grayscale or 3-band RGB. That is how bands will be interpreted by default, as that is what gets displayed using current display technologies. If a dataset uses anything else, like infrared wavelengths, GIS tools can be used to remap those bands to RGB. Elevation is always single band.

Range and units: Imagery usually comes in classical gamma-corrected "colors", but may also be HDR. Elevation is usually stored as meters relative to reference ellipsoid, but that may differ. GIS tools can be used to fix any issues arising from those differences, often simply with offset and scale.

Overviews: Although not as powerful as a quadtree subdivision, overviews allow some progressive loading to take place. They are versions of the dataset in decreasing resolutions, which can be computed using GIS tools and stored alongside the main dataset. Even better are wavelet formats such as JPEG2000 and ECW, inherently multi-resolution and with great compression.

ACKNOWLEDGMENTS

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Starry Night by Macao Science Center

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BIOGRAPHIES

Luisa Mak, BSc Physics and Astronomy, works as a "Planetarium Officer" at Macao Science Center Planetarium since 2009. I have worked in the preparatory group of IPS-Macao International Fulldome Festival 2014.

ABSTRACT

Macao Science Center (MSC) Planetarium started "Starry Night" which is a series of activities for popularizing science and astronomy in July 2015. This series target general Macau citizens over 12 years old with free admission. Two events would be held each month, one skyshow under the dome and one outdoor observation, mainly on Saturday afternoon and evenings. Till May 2018, 41 skyshows and 18 observations were held. An average of 45 attendees was recorded for each skyshow and 263 for each observation.

INTRODUCTION

This series is called "Starry Night" because light and air pollution is severe nowadays. Macao City is also known as the Las Vegas of Asia, hotels and casinos are particularly using excessively decorative lights. We can hardly have good chances to look at a night sky full of stars, so we need to come to the Planetarium to immerse into the night sky, to enjoy the surrounding and at the same time bring some science knowledge home.

I. ROLE OF MSC PLANETARIUM

I.1 Macao Science Center

The building of MSC was designed by Pei Partnership Architects in association with I. M. Pei. It includes an Exhibition Center, Convention Center and Planetarium. We aim to promote science popularization and education among local adolescents, compliment tourism development in Macao and provide a regional platform for science education, convention and exhibition.

I.2 Planetarium

MSC Planetarium is the one and only Planetarium in Macao to serve as a tourist attraction and to provide a platform for science education especially in Astronomy.

It includes a dome of diameter 15.24m, using 12 Sony SRX-T110 projects, 14 renderers (GPU) with NVDIA Quadro P6000, Sky-Skan, DigitalSky Dark Matter Software to have 8K 3D projection. The current renderers and software were installed in November 2017 discarding the old machines. It is recognized as the world's highest resolution 3D Planetarium by Guinness World Record. Each of the 127 seats is equipped with a headphone for translation.

II. PLANETARIUM OPERATION

Daily Operation mainly includes movie screening, skyshows and activities.

II.1 Movie Screening

MSC Planetarium screens 3 shows each day during weekday and 6 during weekend. The average attendance is 43 audience/127 seats, i.e. 34% during 2017. In this paper, more about activities will be discussed.

II.2 Skyshows and activities

We divided "skyshows and activities" into two types:
1. Originated from MSC Planetarium for public and
2. Request by groups and custom made.

From the opening of the Science Center in 2009 till mid 2015, only around 2 or 3 activities were held each year by the Planetarium team. Staffs have not got sufficient chances to get familiar with skyshow preparation and operation. Functions of the Planetarium cannot be fully used, so we decided from July 2015 to increase the number of activities, make it a series and give it a brand name called "Starry Night".

After we have the "Starry Night" series, we made what we do visible by sharing information on social media. With the help of promotion through more and more social media, local groups realized the existence of planetarium and what it can do; we started to have groups to book skyshows about particular topics of their interest.

III."STARRY NIGHT"

"Starry Night" as mentioned above is the brand name of our series of activities for popularizing science and astronomy since July 2015. It is initiated with its Chinese name "Dian Liang Xing Chen", which means to light up the stars again. We hope to raise the awareness of the public to the dark night sky. The logo is already out when we have our first event. We have some astronomical elements in the logo, such as a telescope, the Moon, Big Dipper and our planetarium. This series target general Macao citizens over 12 years old with free admission. Two events would be held each month, one skyshow under the dome and one outdoor observation, mainly at 17:00 Saturday. The 17:00 movie screening on Saturday was found to have the fewest number of audiences during weekend. Each skyshow is 45-75 minutes. With a brand name and regularly appearing in front of the public can make them remember us.

Till May 2018, 41 skyshows and 18 observations were held. An average of 45 attendees was recorded for each skyshow and 263 for each observation.

Figure 1 – "Starry Night" Logo

Trend of the number of audience was increasing during these 3 years. See figure 2. Figure 2 shows the number of audience for each "Starry Night" event, date was used on the x-axis instead of event title to show its trend along time. From here we can see that there is a habit of coming to the planetarium developed between our audiences. Although we do not have a statistic about returning audience, we have 10-20 familiar faces keep turning up in our events.

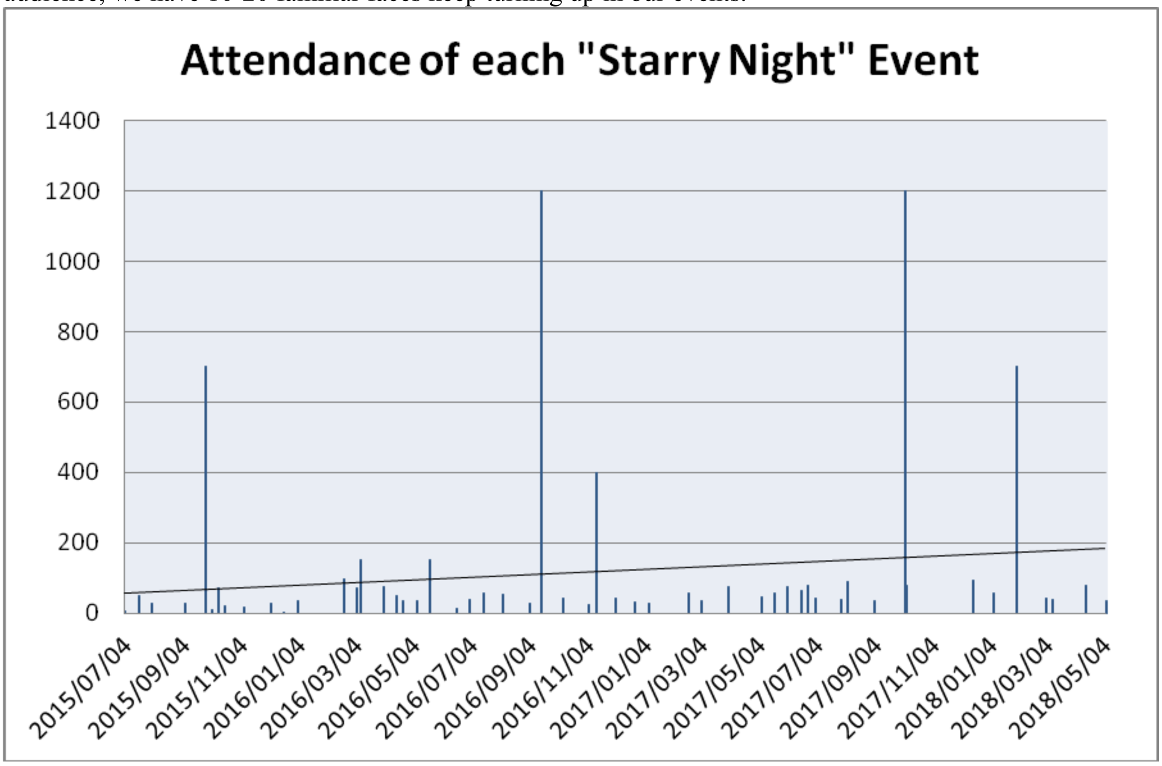

Figure 2 – Number of Audience for each "Starry Night" Event

III.1 Preparations

The annual plan of all the events in the following year is made in September to November. Presenters from universities, astronomical societies are invited; topics are talked over and decided. We invite presenters from the local and neighboring cites, e.g. Hong Kong. We tend to have topics that are down-to-earth, easy to understand and entertaining. As presenters are not familiar with the Planetarium system, they made a powerpoint or rundown of what they would like to present on the dome, including pictures, text and visual effects. Our planetarium staff request for all the information from the presenter at least 3 weeks before the date of event. In the following 2 weeks, planetarium staff made a full understanding of the presenter's idea and put their content on the dome in some "fancy" ways. One week before the date of event, we usually have a rehearsal or at least a video of the dome content if the presenter cannot come to the planetarium. Any arrangement, approval and budget should be made before the beginning of year.

III.2 Content

In the vast ocean of astronomy information we tend to have topics that are down-to-earth, easy to understand and entertaining. Here we have some examples about how we set our topics in:

1. Observation
2. Theoretical Astrophysics
3. Astronomy
4. Humanity
5. Travel
6. Astrophotography

Figure 3 concluded the occurrence of events in these 3 years. 59 events were held till May 2018. Aside from the 26% of observations, we have 74% of skyshows. The original plan was to have 1 observation and 1 skyshow every month. After some cancellations of observations because of clouds and some additional skyshows of special events such as Shaw prize or discovery, the number of skyshows outranged observations.

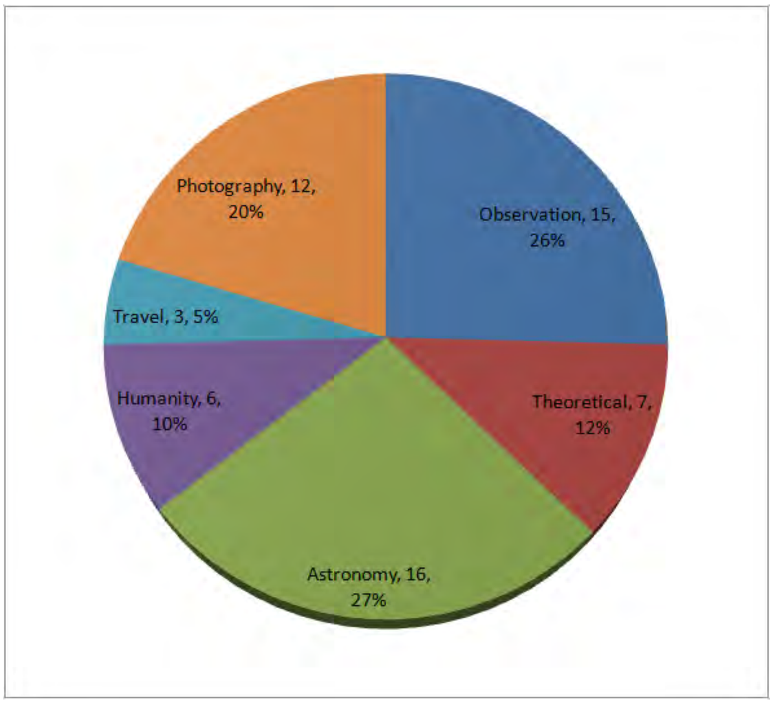

Figure 3 – Types of events (Type, Number of Events, percentage of occurrence)

Figure 4 shows the average number of audience for each type of event. Observation is found to be the most popular type of event.

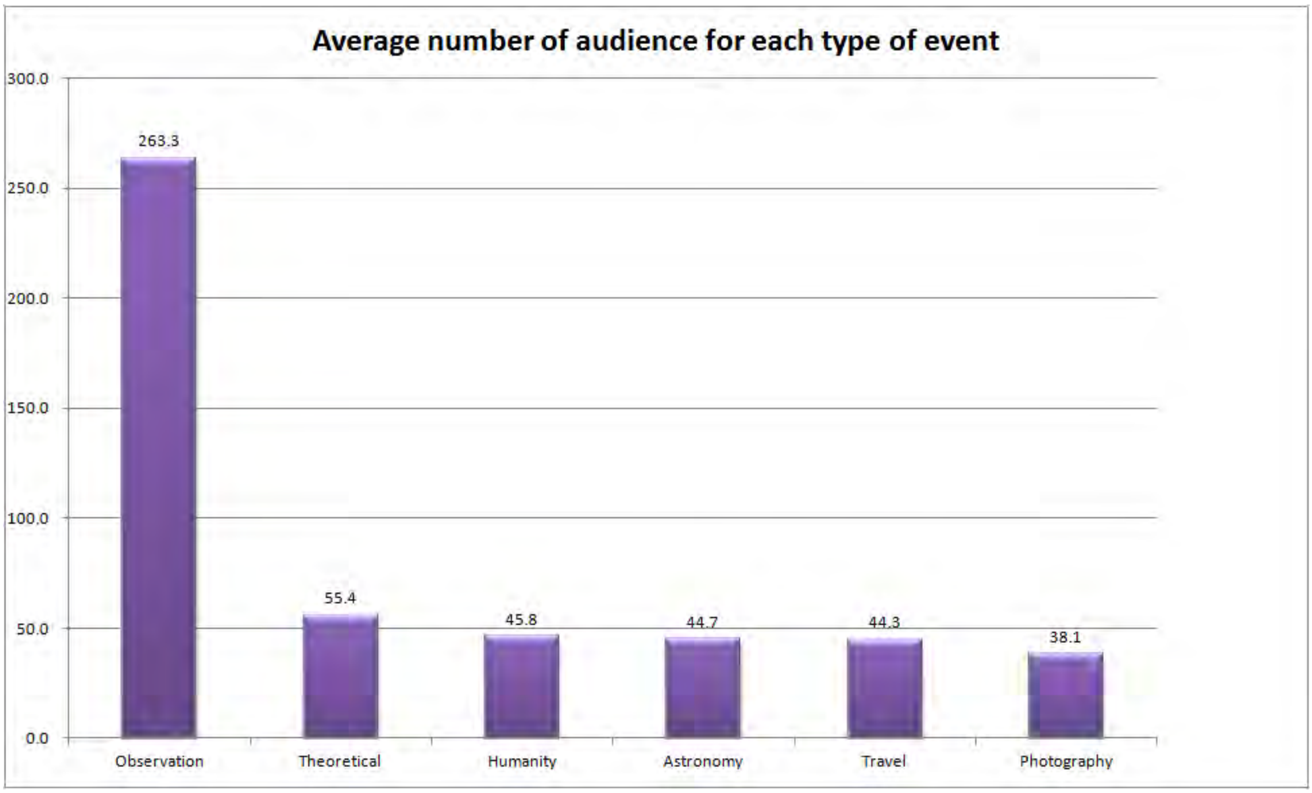

Figure 4 – Average number of audience for each type of event

Examples:
Finding resources of fulldome content is always difficult. We have experimented a lot on how to make things look “COOL” on the dome. We use 3D text, animated text, different fonts, design, animations, etc. Those effects may not affect the content itself or understanding of the audience about the topic but enhance the experience, enjoyment of the audience inside the planetarium.

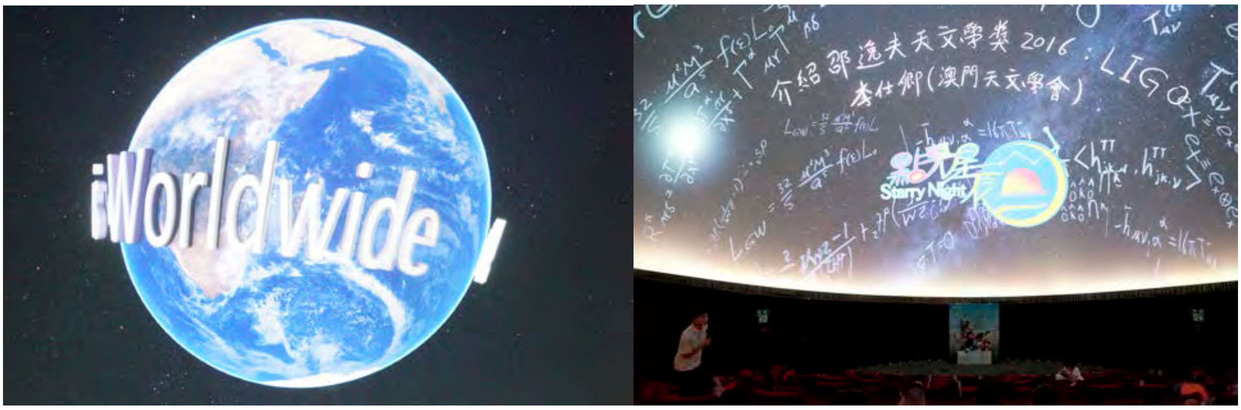

Figure 5 – Examples of fulldome effects used in “Starry Night” skyshows

1. Observation
Telescope with equatorial mount will be set up. For brighter objects such as the moon and planets, telescopes can be set at Macao Science Center. In case of lunar or solar eclipse, we usually set telescopes outdoor as well as capture live feed from other locations on the dome, so that we can still watch the astronomical event together if the weather is not satisfactory. For constellations and darker objects, we will have observations at the far side of Macao away from light pollution. Star Charts are brought and distributed to the audience. The star charts help to find constellations and more importantly, promote our “Starry Night” series.

2. Theoretical Astrophysics
Theoretical astrophysics topics usually includes astronomy that is not easily visible with naked eyes or telescope, these topics are hard and maybe not so attractive to general audience, so we choose the Shaw Prize of Astronomy and Nobel Prize of Physics award winning topics, i.e. Kepler Space Mission, LIGO and Computer Reconstruction, etc. Others include evolution of stars and about blackholes which are also fascinating.

3. Astronomy
Astronomy topics can make good use of our planetarium system. Explanation of different astronomical events, objects and mythologies of constellations are always popular. The skyshows can be repeated. See Figure 7 for an example of constellation labels that will make the skyshow a little bit different each time.

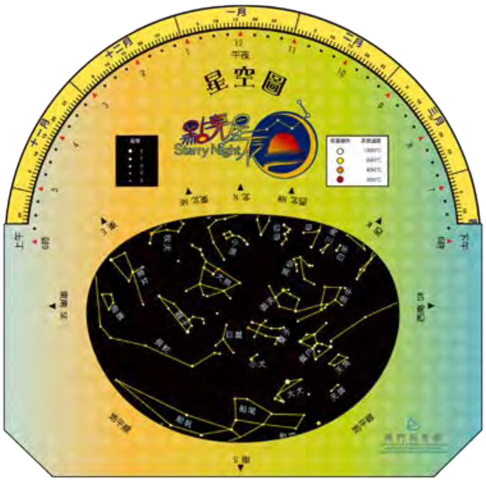

Figure 6 – Planisphere of Macao, produced by MSC

Figure 7- Example of constellation labels

4. Humanity
To make people realized that astronomy is not very far away from our lives, it can be seen in everyday lives. History and development of astronomical studies were discussed. We especially talked about how some astronomical events affected the plot of comics, animation and movies. Science fictions can attract a great number of audiences.

5. Travel
Travel is a new type of topics added to 2018 “Starry Night”, presenters share their experience of star gazing in other places. So far we have talked about Hawaii and Australia and will talk about Aurora in North America later on. In these skyshows, most of the content will be photos taken by the presenter, so we pay more attention on how to present pictures on the dome, e.g. made the pictures as 3D objects, see Figure 6, to make those picture looks “cool”. Presenters can give us photos taken by fisheye or 360 camera to put on the dome.

Figure 8 – Pictures appear as 3D objects on the dome

Figure 9 – Fulldome picture taken by a presenter

6. Photography
For photography session usually includes a skyshow of teaching how to take astronomical pictures, how to find targets in the night sky and example pictures of the presenter; then an outdoor practice to obtain some photo elements and another session in the planetarium for post-processing. Capture function is used to show how the presenter works with the computer softwares.

IV. PROMOTION

Another most important part of the “Starry Night” series other than content is promotion. Posters were especially designed for each month, usually combining 2 events. The design is then converted to different formats for different sizes of printouts, such as posters, leaflets, web banners, etc.

Before each event, we post invitation on facebook, weibo and website. Photos and sometimes videos were taken for reviews on social media such as Macao Science Center facebook page to make people aware of what we do. We put a lot of resources on recording the events. This helps to attract people to come for the following events. Also, the number of booking for customized skyshows and activities increased. We charged for customized events while "Starry Night" is free. The school group events in Macao are usually sponsored by the government. We made an income from the groups to compensate with the free events. The number of customized event is actually more than that of "Starry Night". Those events were also recorded and shared on social media. We tried our best to make media exposure high.

Figure 10 – Example of event posters

V. HUMAN RESOURCE

All the events: "Starry Night", customized events, movie screening, etc, were prepared and operated by 6 staffs of the planetarium team in Macao Science Center. Each of us can operate the planetarium system, equipped with a offline "Dark Matter" software, familiar with organizing events, media as well as being creative. Each staff has been responsible for more than 10 events in 3 years.

VI. CONCLUSION

This paper concludes the 59 events in a "Starry Night" series designed by Macao Science Center since July 2015. We have an increasing number of audiences. Some examples of event types, content and ways of presentation were shown. Our staff makes a great effort on the quality and quantity of events. Promotion is equally important as the content itself. "Starry Night" free events with promotion lead to a large number of customized events thus income. This is how we tried to make good use of our planetarium.

We bring stars closer: the practice of regular public dark sky observations

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Irkutsk Planetarium

BIOGRAPHIES

Pavel Nikiforov, an amateur astronomer since 1989, an executive director of Irkutsk Planetarium since 2016.
Evgeniia Skaredneva, a PR manager and a live presenter in Irkutsk Planetarium, member of Russian Association for Communication in Education and Science (AKSON).

ABSTRACT

Considering our motto "We bring stars closer" the main goal of Irkutsk planetarium is to give the opportunity to the most amount of people to look at the celestial objects through a telescope. In August 2015 the Irkutsk planetarium started outdoor observations of deep sky objects on every empty Moon period. How can the private planetarium develop the profitable business model of month to month public observation? What will happen in your planetarium and in community when you open your outdoor activities opportunity for visitors of the planetarium and community? What can the Planetarian society do to preserve the areas with dark sky accessible for people?

INTRODUCTION

The basis of astronomy is the visual sky observations. Human beings need to get a feeling of the big Universe by their own senses. A very simple way exists: to put the telescope on the ground and look through it.

I. HISTORY/REGION

I.1 Before the Irkutsk Planetarium

Eduard Zuev (1934 – 2005) was the legendary person for amateur astronomy in Irkutsk. He founded in 1989 and managed till his death the Irkutsk amateur astronomy club. Members of the club built the telescopes and showed the celestial objects to everybody (especially schoolchildren) through these telescopes.

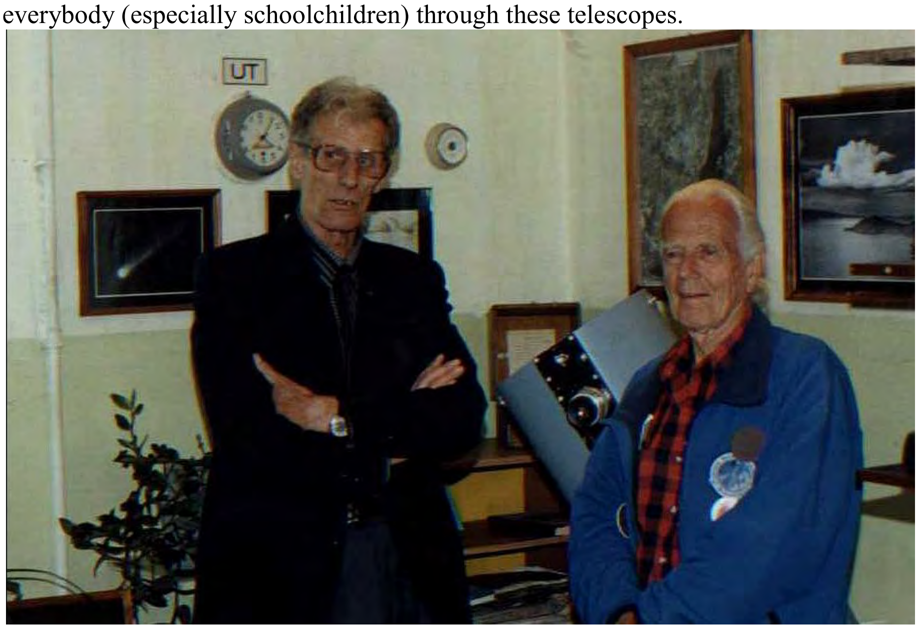

Figure 1 – Eduard Zuev and John Dobson, Irkutsk, 2002

I.2 Irkutsk Planetarium period

In the year 2015 the private Irkutsk Planetarium was opened. It has 9 meter dome and 45 seats. The annual attendance is 40 000 people.
The Baikal region is unique – it is not only the pole of inaccessibility – it is also has a record amount of clear sky days and nights. You can find the Solar-Terrestrial Physics Institute and the Big Vacuum Solar Telescopes on the banks of Lake Baikal.

Figure 2 – The Big Vacuum Solar Telescope

On August 2015 Irkutsk Planetarium performed the first outings: observation of the deep sky objects through the telescope for public.
From this time we conducted 36 series of observations at the Glubokaya site (72 kilometers from the Irkutsk city). By the way, the name of this place means "deep" in Russian, so we observe the deep space at the deep place.

Figure 3 – The Deep Sky Observations at Glubokaya, 2016
The place that we use for our deep-sky observations is the part of federal paved road that is not in use since 2009.

II. PRACTICES

The set of stargazing activities must be profitable. Otherwise, how can you propel them? People are ready to pay money for the qualified guidance on the starry sky.

The set of Irkutsk Planetarium observations activities:

1. **Monthly deep sky objects observations series on the empty Moon periods outside the city (dark sky area).**
   More than 1 000 motivated spectators took part in the commercial all-night long observations of the deep sky objects. The essentials of organizing our deep-sky stargazing activity are:
   a) It should have regular basis (we took the basis of empty moon period);
   b) You should strive for the best you can. For example, we show not only the popular and well-known objects but the hardest and most interesting ones: the faint and distant galaxies, trails of the spacecraft. We depict the latest discoveries and investigations on the sky;
   c) Those who came must have the motivation enough to drive 160 kilometers back and forth in the night along the curved mountain road;
   d) No other activity should have interfered with the stargazing sessions: we gathered to take advantage of the magic opportunity to experience the Universe with our own eyes! No one after he or she saw the stars through the telescopes stays the same.

   We are ready to share our experiences to everyone interested throughout the world.
2. **The non-profit activities alongside with the worldwide Astronomical events** (International Observation The Moon Day, International Sidewalks Astronomy Night, Asteroid Day, International Astronomy Day, etc);
   The best example of this kind of events is the International Sidewalks Astronomy Night (ISAN). Irkutsk was the first city in Russia that participated in the first ISAN in 2007. This year we've organized this event not only in Irkutsk (population 624 000), but also in four biggest cities of Irkutsk region – Bratsk (population 231 000), Angarsk (population 226 000), Ust-Ilimsk (population 82 000) and Shelehov (population 50 000).
   Such activities help us to promote the Planetarium and our mission.
3. **Spontaneous or scheduled Astronomical observations of astronomical events**, i.e. meteor showers, eclipses, oppositions, elongations, occultations, etc.
   These events can be either commercial or free-admitted. In our practice, the observations of meteor showers, solar and lunar eclipses are non-profit – we try to provide such events in the places that can attend a lot of people. But when we organize observations of events that related to the planets (opposition or elongations), we sell the tickets. Such events can take place in the observatory of our Planetarium as well as on the sites outside the city.
4. **Monthly free-admitted public observations in the popular city places: squares, parks**. This activity includes the lecture and observation of the specific celestial object or phenomenon.
   For three years of our work more than 10 000 people were engaged in activities mentioned in 2, 3 and 4.

For most communities the greatest problem for organizing and providing the above-mentioned activities is the exceeding level of light pollution in all of the nearby areas. But still there is the big interest in stargazing events in all the communities.

III.RESULTS

1. Amateur astronomers of Irkutsk region who used to be unseen and was conducting their own seldom observations, become visible and contributing to community. Now, after three years of practice most of them became our volunteers;
2. The geographic expansion is on the way: the more we do the most geographically widespread we are;
3. New activities are permanently emerging due to the free creativity of the members and volunteers.

IV.PLANS

The realm of the dark sky shrinks dramatically. We should join our forces to defend accessible dark sky area reservations. Unfortunately, there are no branches of Dark Sky Association in Russia, and the community in general is not in aware of the fact that we are losing our dark sky.

ACKNOWLEDGMENTS

We do all the observational activities in memory of our teacher Eduard G. Zuev (1934 – 2005).

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Literacy After the Dome

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BIOGRAPHIES

Jack has been the planetarium director at a middle school planetarium for 15 years in Omaha, Nebraska in the United States. He has since opened his own portable planetarium in his home state of Iowa..

ABSTRACT

Applying literacy strategies to the post planetarium experience can extend a students retention of content learned in the planetarium. Reference style books are not the only option for these students as fiction, graphic novel, and art books are also successful. The strategies are designed with scaffolding to support students who have reading difficulties and experience language barriers. Use of literacy strategies can improve the application of vocabulary and synthesis of process or systems from the planetarium presentation. The use of literacy strategies can also assist the students in developing informed questions that can be used in the inquiry process.

INTRODUCTION

As planetarians we are leaders in astronomy and science education however there are times where we must also become instructional leaders. Schools, teachers, students, and families visit your planetarium and for 45 minutes to an hour you are in control of the instruction but what happens when they leave. While some master teachers are able to integrate astronomy concepts into their instruction in the classroom there are times when additional information and scaffolding are useful.

I. SECTION 1

A very useful strategy that many teachers are aware of either formally or informally is Six Step Vocabulary. It is very powerful in assisting the students in mastering new vocabulary terms that are introduced in the planetarium.

I.1 Sub-Section 1 In the Dome

Three of the six steps can be done in the planetarium very successfully. These steps are Example, Restate, Pictures

- Example
    - Provide the students with a description, explanation, and examples of terms. Use everyday vocabulary and avoid dictionary definitions.
- Restate
    - In a planetarium this can get noisy, for this step have the students see if they can come up with a better definition to share with the group.
- Pictures
    - This step is very easy in the planetarium, use the power of the planetarium's immersive environment.

I.2 Sub-Section 2 In the Classroom

The second set of three steps that can be done back in the classroom are; Activities, Discussion, and Synthesize

- Activities
    - This is where a teacher's tool box of instruction is really useful. This is when they an look for analogies, metaphors, affixes, synonyms, and antonyms. Students get to have repeated exposures to the vocabulary words or topics to help move information into long term memory.
- Discussion
    - This is the time where you are seeking deeper knowledge by having the students completing a think/pair/share with the information and Socratic Seminar
- Synthesize
    - This is the time were you are really showing off what you know. Students will take the vocabulary, topic, and concept to create something, This could be a board game, story, comic book, poster, song, or model.

II. Section 2

Reciprocal teaching is a powerful way to have students develop a deeper understanding of a topic using five major attributes.

- Clarify
- Predict
- Question
- Summarize
- Visualization

Let's take a look at using this while studying the planets of the solar system. Like before it will be broken into roles for in the planetarium and in classroom. When used in a single environment you can move between any of the attributes visiting any one of them as many times as needed.

II.1 Sub-Section 1 In the Planetarium

In the planetarium, don't outright say a definition of what is a planet. Instead couch it as a tour around the solar system. After visiting Mercury, Venus, and Earth most students will Predict that Mars is also spherical. During the visits to the Outer planets the students will start to Clarify this idea and add the option that they can have rings and many have moons. Use Socratic questioning strategies to pose open-ended questions to the students like, "What do they have in common?" "Is there a pattern?" and "How are they unique?" These are good starter questions to lead the students to asking their own questions like "Are some moons the size of planets?"

II.2 Sub-Section 2 In the Classroom

After returning to the classroom the students are tasked with Summarizing a definition of "what is required to call something a planet?" They can also create a diagram or a poster to support their definition as part of Visualization. I generally send a sealed envelope back with the teacher with a proper definition of what is a planet since many textbooks use definitions that are very generalized and do not work well for in depth instruction.

III. Section 3

The final technique to be covered is RAFT writing. Let's take a look at this continuing to use the solar system as a topic. After a visit to the planetarium the students use the RAFT as a scaffold to write a story.

- **R** - Role - Astronaut
- **A** - Audience - Their grade level
- **F** - Format - Short Story or Graphic Novel
- **T** - Topic - The first Astronaut to visit ___________

The students get to choose one of the planets in the solar system to send their astronaut selves to and document the mission as a short story or graphic novel.

Other examples on a different topic

A letter home to the ocean from a rain drop on an adventure through the water cycle.

A diary entry for a star in a globular cluster about having thousands of stars nearby.

ACKNOWLEDGMENTS

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Multi-discipline Interactive Programs Under the Dome II

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ABSTRACT GROUP

This is an interactive program about seasonal changes at different latitudes for high school students. The Environmental Science class came to the planetarium for a lesson about climates and biomes. We learned that official climate names are very similar to the names of biomes, which leads to confusion for students. In the planetarium we illustrate the angle in insolation and hours of daylight at selected latitudes during different seasons. Students are challenged to find a relationship between latitude and climate and climate and biome. As a result of the understanding from this program, students then are able to describe planets and animals that can live in specific biomes.

ABSTRACT INDIVIDUAL

"Building a System." In this session participants will work collaboratively to building an exoplanet solar system.

INTRODUCTION

I have the students design an exoplanet solar system as part of a two day visit to the planetarium. The sections of this paper are divided into the parts of the project that are done prior to the visit to the planetarium, day one, evening of day one, and day two.

I. SECTION 1 Prior to visit

Prior to the students coming to the planetarium I send them a worksheet for the students to complete of a 2:1 rectangle that will become the eventual surface of their planet, the name for the exoplanet, and its period of rotation. There are also scales listed for the Mass of the planet (0.1 - 25 M_E), Radius of the planet (0.1 - 25 R_E), and Distance from the Sun (0.1 - 50 AU).

II. SECTION 2 Day 1

During the visit to the planetarium we tour the planets of the solar system focusing in on the effect of tilt on their seasons or variation of length of day time. Toward the end of the presentation the students are tasked with choosing the tilt for their planet ranging from 0 to 180 degrees. The worksheets are collected as an exit slip as the students are leaving the planetarium.

III. SECTION 3 Day 1 (evening)

That evening I scan and load the information off the worksheets into the a text file that is read by a Python script to create our class's solar system. It normally takes about four hours to render the images and then minutes to load it into the planetarium. On average each student's planet requires 1500 frames to complete.

IV. SECTION 4 Day 2

During the second visit we start by looking at the analema and how it would vary on each planet and see some examples such as Mars, Jupiter, and Neptune. Then we transition to a show and tell mode where the students begin to tour their exoplanet solar system. Management wise, I am still controlling the pace but the microphone is passed around to have the students tell a little bit about their planets.

V. SECTION 5 Post Visit

After the visit to the planetarium I export the trip through their solar system as a movie file that is uploaded to YouTube for the students to show off their planets to friends and family. Since it does not include personal data the students don't have to have releases signed and if the planet pattern has something questionable it is mysteriously edited while I am overseeing the scanning. Most of the time I can just cover it with a copied part from another area of their pattern.

ACKNOWLEDGMENTS

I want to thank Teresa Bender, Jodi Decker, Diane Hoffmann, and Darci Pressnell-Marter for letting me test this lesson with their students.

Community Observatories: Going Beyond the Dome to Bring Science Education to Rural Communities

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Suikerbosrand Nature Reserve *June2018*

I have walked that long road to freedom. I have tried not to falter; I have made missteps along the way. But I have discovered the secret that after climbing a great hill, one only finds that there are many more hills to climb. I have taken a moment to rest, to steal a view of the glorious vista that surrounds me, to look back on the distance I have come. I can only rest for a moment, for with freedom comes responsibilities, and I dare not linger, for my long walk is not ended.

- Nelson Mandela

BIOGRAPHY

Jonathan Padavatan is Presenter and Senior Technician at Wits Planetarium, University of the Witwatersrand, Johannesburg. Besides maintaining the world's oldest working star projector, he presents shows to school children, university students and the general public. Jonathan has a BSc (Honours) Physics degree and is completing his MSc in Computer Science.

ABSTRACT

Rural South Africa possesses one of the most inspirational forms of natural beauty: the night sky. This paper explores the possibility of establishing community observatories at suitable locations in South Africa, using astronomy as tool to improve science and maths education for school children in under-resourced rural areas. Communities around the observatory would hopefully be encouraged to regard the clear night sky as a natural resource worth preserving and protecting. Africa can reunite with her ancient wisdom by exploring her ancient skies.

INTRODUCTION

Astronomy has an unparalleled power to make maths and science accessible to school children. At Wits Planetarium in Johannesburg, South Africa, presenters use this power on a daily basis to spark an interest in science and show learners that they can master mathematical concepts that they perceive as abstract and very difficult.

In South Africa, the country's Apartheid legacy is starkly evident in our education system. Private schools and government schools in affluent areas provide quality education, while the majority of government schools struggle with overcrowded classrooms, overwhelmed teachers, and a lack resources and infrastructure. Schools in rural areas are often the most disadvantaged, and many lack computers, science labs, libraries or even a reliable electricity supply[i]. However, the lack of light and air pollution in rural areas means these learners do have access to the greatest and most inspiring natural laboratory of all: the night sky.

The Wits Planetarium is one of the University of the Witwatersrand's main vehicles for science outreach. Over 60 000 school children visit the Planetarium each year, usually as part of school field trips. Besides schools from the cities of Johannesburg and Pretoria, we also receive visits from schools based in the primarily rural provinces of Limpopo, North West and Mpumalanga. One day, while contemplating the irony of children being brought from rural areas to the city to be shown the beauty of the night sky, I asked myself how we could motivate these children to see their natural dark skies as an asset, rather than an unfortunate side effect of underdevelopment? There are probably many answers to this question, but the one that I hit upon was the concept of a community observatory.

I. WHY A COMMUNITY OBSERVATORY?

Children are natural scientists. They explore their environment, study the world around them, conduct experiments (what happens when I bite the ocean?) and draw conclusions from these experiments (sea water is salty and not good to eat). Yet day after day, I encounter groups of school children who find science boring or intimidating. They tell me that science and mathematics are "scary", they lack confidence in their own abilities in these subjects. Many are so disengaged that they have completely given up on learning anything from these subjects, and cannot see the relevance of maths and science to their lives.

In recent years, a growing body of research in neuroscience and psychology has identified weaknesses in traditional teaching methods contribute to the pervasive myth that maths and science are dry, abstract and difficult. Internationally, educators are moving towards teaching methods that focus on an experiential, project-based approaches, which build upon children's natural ability to learn by engaging with problems in the real world, rather than by reading about them in text books[ii]. Experiential learning, where learners explore information in practical and creative ways, helps children who are already engaged with a subject to excel, and those children who have lost interest to re-engage and begin learning[iii].

The Planetarium is an ideal venue for exploring maths and science in exciting, creative ways. Space travel, like dinosaurs, is one of those branches of science that grips young minds and ignites a passion for science. In almost every field of science, you will find eminent professors who owe their initial interest in scientific matters to either Carl Sagan or T Rex. But for children who have lost all faith in their own abilities, and who worried that they will not be able to get a job at all because they cannot pass even the most basic maths test, the Planetarium is also the ideal place build new confidence, because learners can relax and immerse themselves in wonder and beauty.

For example, I use this very simple exercise during shows: after enjoying the star field for a few minutes, I point out the summer triangle of southern skies, comprising the bright stars Sirius, Betelgeuse and Procyon (see figure 1). I then ask the learners to identify the isosceles triangle, and lead them in a discussion on which two sides are equal. I then inform the learners (who 10 minutes before complained that maths was a terrifying subject) that they are actually doing maths.

Figure 1 – The summer triangle as a geometry exercise

Techniques that are effective under the dome can also be taken outside under the stars, and the Wits Planetarium has a long history of outreach and community engagement. In the late 2000's, the Planetarium (then known as Johannesburg Planetarium) ran a project called the Astro Hit Squad, which involved mentoring a group of high school learners, many of whom came from disadvantaged backgrounds. They participated in astronomy events, did science projects, and took telescopes into the streets of the inner city and townships around Johannesburg, to engage passers-by in impromptu star-watching sessions. Several Astro Hit Squad members went on to study at Wits University and embarked on careers in science, including Dr Sheldon Rhameez Herbst, who maintains that the mentoring and inspiration he received in the Astro Hit Squad as a teenager was a key motivating factor that led him to a career in computational astrophysics. In a testimonial in support of the community observatory project, Dr Herbst said, "As an applied mathematician doing research in computational astrophysics I am still fueled by the same sense of intrigue that was fostered in the Astro Hit Squad…. It is without doubt that the Planetarium's Astro Hit Squad has contributed significantly to the scientist I am today and that the creation of such initiatives is fundamental for the scientific development of young children."

The Astro Hit Squad programme showed the power of extra-curricular science projects to improve school maths and science results and to make further study and careers in science accessible to young people who might otherwise not have had this opportunity. By taking similar programmes to rural areas, disadvantaged children in these areas could be given similar opportunities. In addition, the growth of the astro-tourism industry in South Africa provides an opportunity for direct job creation, by training community members to act as "sky guides" at the many holiday resorts, luxury game lodges and wild life reserves that are now offering star watching as a tourist activity. Tourism is perhaps the only industry which has the potential to create jobs and economic opportunities in rural areas, at a time when the large employers in these areas, mining and agriculture, are shedding jobs. The community observatory would therefore be an asset to the entire community, not just to schools.

After staring at the Africa at Night images from space for a while, I saw the potential for expanding the horizons of nature conservation by linking local eco-tourism with the international dark skies movement. Rural communities would have a tangible reason to become guardians and protectors of their dark skies. They could also promote indigenous knowledge systems and traditional star lore.

With this as very strong motivation, I then set out to identify a suitable site for a community observatory pilot project.

II. A BUMPY RIDE ON THE ROAD LESS TRAVELED

As our Planetarium is based at Wits University, the obvious first choice of site was the Wits Rural Facility (WRF), a nature reserve and research facility owned by the university. Situated in Acrornhoek, near to the Kruger National Park, WRF seemed to be an ideal site. It has clear, dark skies, is located in a low rainfall area, and is accessible to a large number of nearby village, farm and township schools. It also has existing accommodation, conference and teaching facilities. In April 2017 I visited WRF to assess the site, and make contact with stakeholders. I subsequently drew up a concept note for a small observatory to accommodate both the public and school groups, consisting of an 8 inch to 12 inch telescope, and a structure to house the telescope. The observatory was envisaged as a joint project between Wits University and the local community, with activities such as school visits; school holiday programmes; training programmes for teachers on how to use the night sky as a natural laboratory; star-watching evenings for tourists; training programmes for sky guides in the astro-tourism industry; and corporate team-building events combing astronomy with a bushveld experience. Teachers at local schools expressed a great deal of enthusiasm for the project.

However, it soon became clear that obtaining funding was going to be formidable challenge. The project did not fit neatly into any one category, and did not seem to meet anyone's funding criteria.
I applied to Astronomy for Development, who declined to fund it on the basis that they were not sure of the educational value of the project.

I then approached Wits University, and was referred to the Global Change Institute (GCI), which runs climate change and sustainable development projects at the WRF. They could see the value of the community observatory as a science outreach project, but it did not fall within their mandate. (On the bright side, I formed a friendship with Professor Barend Erasmus of the GCI, who recognized the link between my dark sky agenda and more efficient lighting to lower energy consumption. I was subsequently invited to join Wits sustainable development on campus forum created by the GCI).

I also approached various private sector stakeholders, and everybody *loved* the idea and saw great potential for income generation, but nobody was willing to provide the start-up capital.

In the interim I had also been discussion with the Square Kilometer Array (SKA) telescope project, South Africa's premier astronomy project. They are currently considering potential science outreach projects, but are engaged in their own project selection process. A community observatory was one of the ideas under consideration, however they are focused on the SKA telescope site in the Northern Cape, whereas the Wits Rural Facility is quite literally at the other side of the country.

It therefore appears that despite the great potential, there is not much chance of establishing a community observatory at the WRF, at least in the short term. The lessons I have taken away from this process are the difficulty of fund-raising for a project that cuts across the different areas of education, science outreach, job-creation and nature conservation; and pit-falls of conceptualizing a project in isolation and then trying to sell it to others. Projects such as this, which involve many different stakeholders, should preferably start out as partnerships with local champions, who share a passion for science education, and all stakeholders should co-create the shape and content of the project.

III. BUT... WHERE THERE'S DARKNESS, THERE'S HOPE

In 2018, Wits Planetarium was accosted by the chairperson of a passionate group of nature enthusiasts, the Friends of Suikerbosrand. Suikerbosrand is a nature reserve situated approximately 50 km from Johannesburg, and is one of the few nature conservation areas in the largely urban and industrial Gauteng Province. The Friends of Suikerbosrand are a group of volunteers who are committed to preserving this piece of wilderness. They are interested in astronomy, see the value of promoting dark skies as part of nature conservation, and it was clear that I had no other choice but to haul a telescope up a mountain and provide them with a star-watching evening.

Omega Centaurus is one of the most spectacular features of the Southern Skies. That cold night (it was around 2 degrees Celsius) we could easily see that wispy smudge almost the size of full moon hanging in the sky near the Southern Cross. The black-backed jackals were calling in the distance,almost mockingly at our search for meaning in the darkness. We were a mere 40 minutes drive from the Johannesburg City centre but we were mesmerized by the 1 million star cluster that filled the field of view of the telescope. Not only were we transported to another time, a time of our far ancestors, but we were transported through our 8inch telescope, to a world that could exist in Omega Centaurus. We imagined the night sky of that world, that frigid night. A spotted eagle owl huu-hooed in acknowledgement. Later on, as we warmed around the fireside, sharing our various states of awe for the cluster, we found a moment of reverence for the darkness. A group of strangers a few hours ago, now a community of observers.

I wonder what effect this experience would have on a young mind from an under-resourced school with little chance of passing her next mathematics test?

The Suikerbosrand reserve is managed by the Gauteng Provincial Government, and the reserve management are interested in exploring astro-tourism at the reserve. The proximity of the reserve to Johannesburg means that it is considerably easier and cheaper for the Planetarium to conduct outreach there, and there are many schools in the surrounding farming and peri-urban areas. I am therefore hopeful that the dream of a community observatory remains alive, but the form it takes will depend on a collaboration between the Reserve Management, local communities, the Planetarium and the Friends of Suikerbosrand.

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Mrs Jane Doherty, who very generously donated her late husband Andrew's telescope to the Planetarium for outreach activities.
My wife, Chloe Hardy, for editorial assistance, and my daughters, Rose and Tara, for accompanying me in my search for darker skies.

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Technology,
What's new after ISE 2018?

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BIOGRAPHIES

Damien Pelisse is Technical Director at RSA Cosmos. He took part in the design and setup of the first full digital planetariums with RSA Cosmos more than 15 years ago. He still like technology a lot and never avoid to go on field and work on systems all night long!

ABSTRACT

ISE (Integrated Systems Europe) is the largest AV and systems integration show in the world. It took place from 6th to 9th February 2018 in Amsterdam.
In this yearly showcase, all projector manufacturers demonstrate state of the art projection technology.
From projection chip to light source or resolution... There's many to see!
After reviewing last year's trends, is there something new or different which applies for this 2018 showcase?

Have different vendors a different approach to the technology?
The idea is to give an extended view on the projection market from a vendor point of view taking into consideration what users are expecting.

INTRODUCTION

What are the criteria to evaluate in a projector and what do we specifically look for in our market?
Brightness, Contrast, Resolution, Color space are primary technical criteria.
You shall also be interested in the Total Cost of Ownership (TCO) of each projection solution which at some point makes a difference!
We should have all these information when trying to evaluate a new projector.

Know that in this paper, we'll go a bit further than the ISE. Everything is not shown at this showcase.
Some products are showed in "whisper rooms" and some are just in roadmap which sometimes are subject to NDA (Non-Disclosure Agreement).
Please note also that in this paper we won't review LCD projectors as we consider that they are not fitted for our market.
We'll try anyway our best to review the market as it is today!

I. CONTRAST

Let's start with one point we usually consider a lot in planetariums: Contrast.
I won't go in the direction on how contrast is important and how we should measure it. Many papers at past IPSs have covered this topic. But I'd like to bring your attention to a new habit in brochures where the shown contrast value is a dynamic contrast.
By dimming the light depending on the content, it is easy to reach a very high "On/off" contrast value.
If it might be a plus in some uses, it is not the case for our domes. The main point is that, at this time, there is no way to synchronize this dimming system over different projectors.
Also, considering a night sky, if the light source is dimmed to have a better black, your starry sky will also suffer from a lack of light.
Just be aware of what numbers you're reading, and as for a lot of technical specifications you sometimes need to dig a bit.

II. NO MORE LAMPS!

Definitely, projection market is becoming lamp free.
If we look for the projectors which are interesting us in the planetarium market, only few lamp projectors remain and they'll be EOL soon. As an example, it is announced by Sony that the well-known SRX-T615 (18000 lumens with 6 lamps) will not be produced anymore.
The advantages of a lamp free projector are easy to find: low TCO and almost maintenance free.
Of course the drawback is that, in most of the cases, the light source cannot be replaced.
In the "no lamp" projectors market, different approaches exist in what we call "Solid-State Illumination"

II.1 LED based projectors

They offer advantages like a very compact size and a system without moving parts which dramatically reduces the failure rate.
Also, in matter of colors, they're doing good, going beyond the Rec. 709 color space.
On the other hand, the brightness is limited to values around 4000 lumens and the choice is limited to DLP projectors.
This kind of projectors wasn't represented that much at ISE.
At this time, we know that Norxe (not showing at ISE) is trusting in this light source for their range.
Barco was offering the FL35 but we'll see below that we feel their strategy for compact projectors is going to Laser Phosphor illumination.

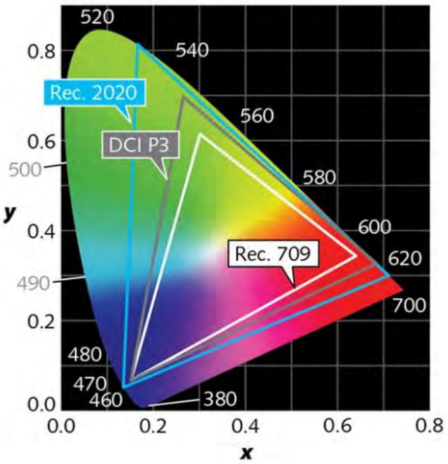


Figure 1 – Rec. 709 vs Rec. 2020 in color gamut

II.2 Laser Phosphor

With this kind of projector the brightness range is wider, from 2000 lumens up to 35000 lumens.
They are quite compact, flexible (no position constraint) and give reasonable colors meeting Rec. 709 color space.
This technology is now well controlled and well spread in the market.

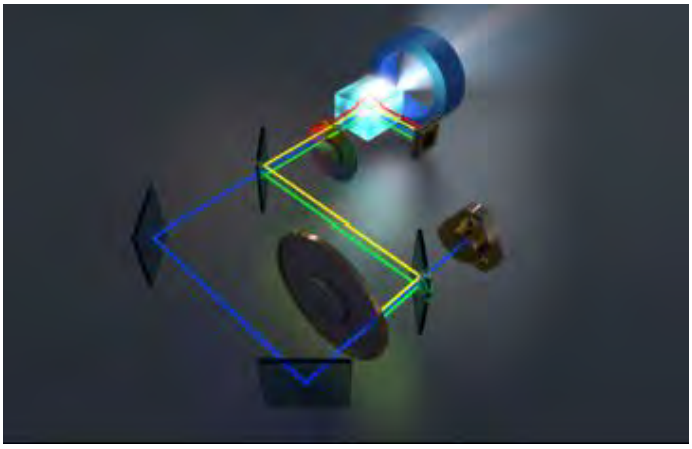
We could see a lot of new projectors in this range this year:

JVC will offer the DLA-VS4010 as a replacement to the lamp based SH-7. With a native 4K resolution, it will be 6000 lumens and keeps all the advantages of the JVC D-ILA chip (10000:1 contrast ratio)

JVC also widening the DLA-RS series. Even if they are more targeting the home cinema market, they might be used in multi-channel setup where their incredible contrast (up to 100 000:1 native) remain an advantage. Native resolution is 4K as well.

Sony is introducing the VPL-GTZ240, it's a kind of compact version of the VPL-GTZ280. Offering a 2000lm brightness with Sony's SXRD chip. It keeps a native contrast ratio of 16000:1 and a native resolution of 4K as well. Somehow the great contrast of these projectors counterbalance the color space limited to Rec. 709.

Barco also puts an accent on this technology with the new F series (F70 80 & 90). With brightness from 6000 lumens until 12000 lumens. They are offering a native resolution of 2560x1600 and are single chip DLP based. Keeping then a color wheel and a limited native contrast.



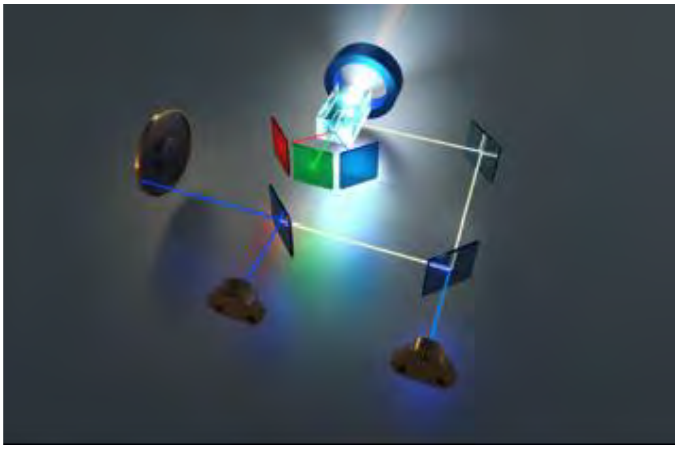


Figure 2 & 3 – Laser Phosphor Light Path for 1x DLP (left) & 3x DLP (right)

Many Laser Phosphor projectors can also be found in the catalog of other vendors like Optoma, BenQ & Panasonic.
It is not possible to make an exhaustive list of them. They can be single or tri-chip DLP.

A variant of laser phosphor can be found at Nec with the 4K PH3501QL.
It uses an additional Red laser to wider the color space of the projectors which are then better than the "regular" laser phosphor.
With his 35000 lumens it will target large theaters.

Christie also brings the new Crimson to the market with similar technology.
It keeps the well know Boxer chassis and offers 25000lm of illumination. Unfortunately, it is not available in 4K.

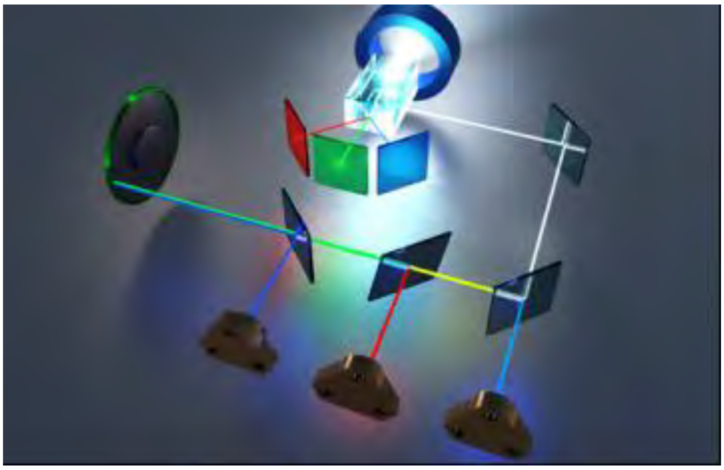


Figure 4 – RB Laser Light Path, 3x DLP

Know that for all these projectors, the light output will decrease with time. Given brightness is obtained with a new projector.
In a general way, brightness drops to 50% at the end of life of the light source (usually 20000 h).
Some vendors, like Sony and Panasonic, can offer a "Constant Brightness" mode. Projector initial brightness is decreased but on the other hand you avoid the disappointment of a dark system after some running time. It also allows to extend the projectors life.
This point must be considered when calculating the amount of light needed for your setup.

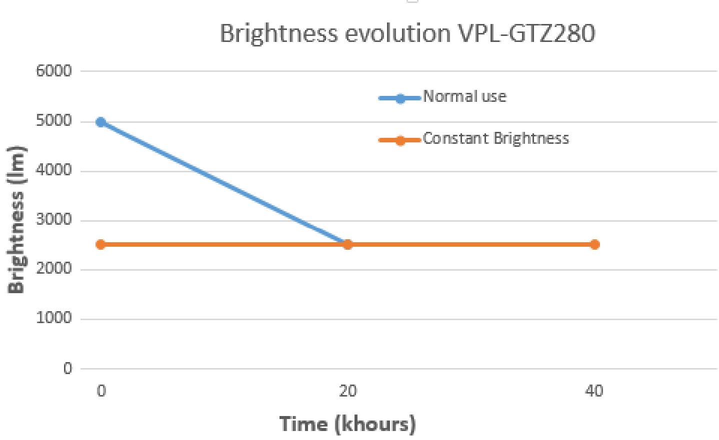


Figure 5 – Brightness evolution with or without Constant Brightness mode (courtesy of Sony)

II.3 Laser 3P (3-Primary)

I did not see any at ISE (6P was shown instead, see next chapter) but this kind of lighting technology is really interesting for the advantages it brings.
Allowing really bright projectors (up to 60000 lumens) they reach Rec. 2020 color space and bring the best color.
It also have a better behavior over time, letting us expect 80% of initial brightness after 30000h.

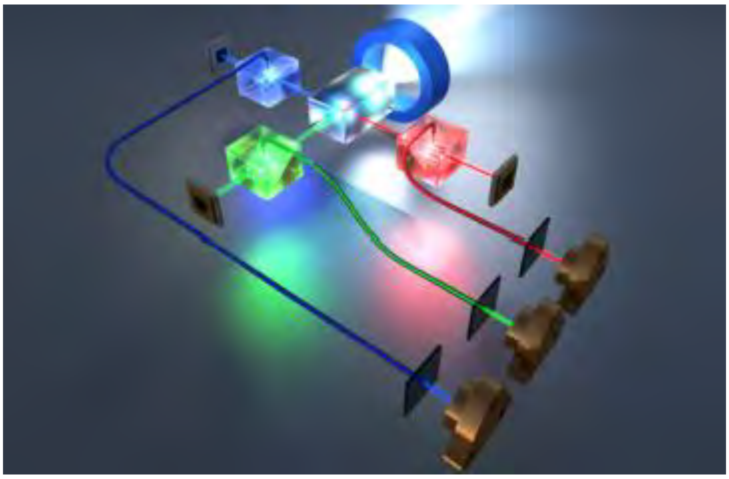


Figure 6 – RGB Laser Light Path, 3x DLP

II.4 Laser 6P (6-Primary)

Basically same as 3P but a second set of 3 lasers is used with slightly different wavelengths.
It allows with the appropriated glasses to offer state of the art 3D Cinema with best colors in 3D.
Each glass let pass the light from one of the laser set, allowing the separation of left and right eye signal.


Figure 7 – Separation of light of a 6P source in 3D application (courtesy of Christie Digital Systems Inc.)

Barco and Christie are both leaders on this range of products.
Primary target for these products at this time is cinema.
The Barco XDL-4K60 took a good place on their booth at ISE, delivering a 60000lm image on a 5m dome.

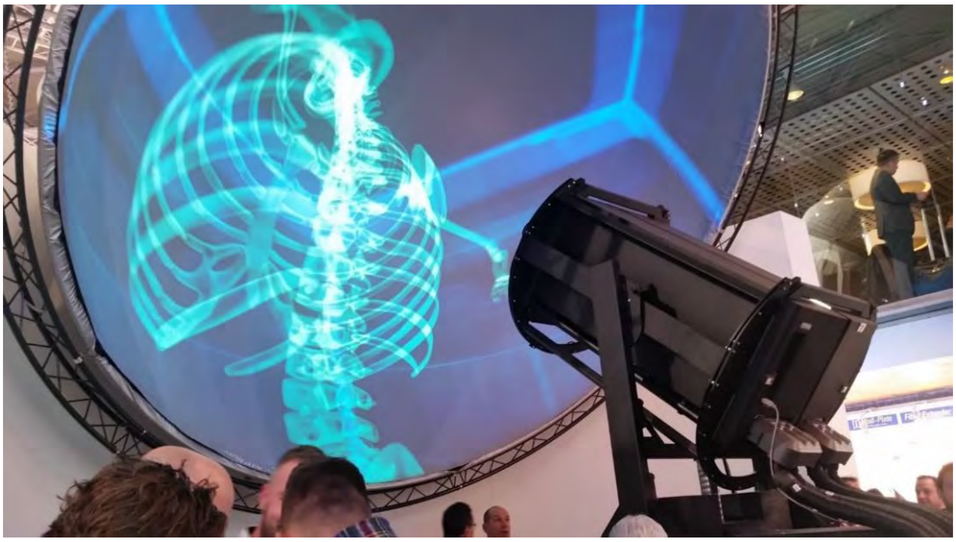


Figure 8 – Barco XDL-4K60 in action at ISE 2018

Still, these products are extremely big and they need a dedicated cooling unit. This cooling unit is as big as the projector. Know also that such a projector at full power draws a power of 10kW (projector + cooling unit).

Christie's range was not shown at ISE and specifications was only preliminary, but we can expect similar specs.

III.MORE BRIGHTNESS!

The previous chapter let us see that we can reach very high values of brightness.
We could not imagine such brightness few years ago!
Also, as large projectors reach these level of brightness, the ratio "brightness / projector volume" increases.
We can easily have brightness of 10000 lumens where a projector of same size reached only 2000 lumens few years ago.
The F series from Barco is the perfect example of this evolution.

In a same comparison, large projectors can now reach 30000 lumens with the size of what was a 10000 lm 5 years ago.
The large 60000lm are still not for all domes, but we can imagine that they'll be more compact in the future

With all this amount of light in our domes, we can offer much brighter solutions than in the past. This amount of light is very useful when you're coming to 3D. (keep in mind that after 3D glasses, only ~20% of light remains for the eye).
We can now provide pretty bright 3D solutions in large domes with only 2 projectors.
It brings nice 3D pictures to the dome with a total cost of ownership that remained reasonable.
The Digital Projection Insight Dual Laser is a perfect candidate for such applications. It is not a new projector, but it has been recently introduced with 120Hz processing capability, expending his range of uses.

It is clear that the increase in brightness is closely linked with the development of new light sources like the Laser 3P & 6P.
Their market share was very low in 2017, but we need to look forward for these products in the next years.

SXRD & D-ILA chip remain (at this time) out of this race. We need to watch carefully if things are moving on this side.

IV.MORE PIXELS... WITH SAME MATRICES...

We spoke only a bit about resolution, but if you look closer into the manufacturer catalogs, you'll find a lot of "4K UHD+" projector. So... These projectors are 4K? Not exactly.
They are not really using a native 4K chip and they try to increase the resolution with a process called wobulation (or e-shift for JVC). This process was explored more than 10 years ago by Hewlett-Packard R&D teams.
By applying this technique to the Texas Instrument's chip, the visual resolution can be increased.

At this time, Texas Instruments is offering to projector manufacturers the following chips:
WQXGA (2560*1600) for single-chip DLP & 4K (4096*2160) for tri-chip DLP

So, there is no way for manufacturers of single-chip projectors to deliver native 4K projector.
As there is a huge demand for 4K on the market, this is a not so bad solution to offer 4K resolution at a reasonable price.

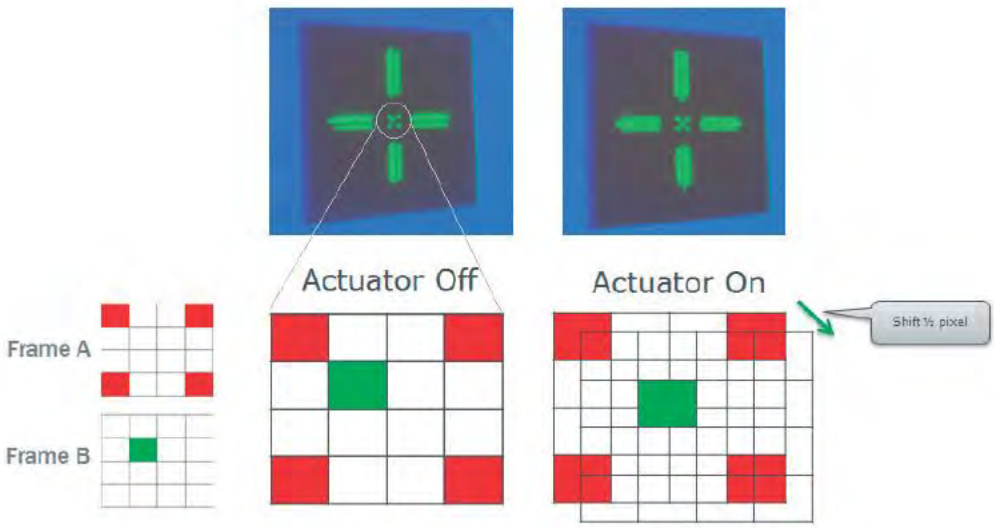


Figure 9 – Use of A frames & B frames in Wobulation

Basic implementation of this technique is to use the DLP chip with a higher refresh rate and to add an optical actuator to shift the image after the chip. Doing this, sub pixels are created. Above is an explanation by Barco of their implementation of this technique (fig 9).

So, is it bad or is it good... It's hard to see everything bright or everything dark!

We could see at ISE that most of the DLP single-chip manufacturers are going in this way to answer the market requirements for 4K. So, if you wonder about a "real" 4K resolution, make sure to always check the native resolution when comparing projectors. It is sometimes needed to dig to find this information!

By the way, note that there are two ways to achieve this.
You can feed the projector with the native chip resolution and let the projector upscale your source image OR you can feed it with a UHD resolution. For sure the first option is nothing good. If you try this, the image may look blurry, and it is not what we expect with a resolution increase! Second option is better, we can now really feel that the pixel pitch decreases by enabling this feature. Just make sure that the projector allows it! For signal processing reasons, some projectors allow only the first option!
Still, in my opinion it is not as good as a native 4K, if you look carefully the principle describe above, you will understand that it is not possible to illuminate a single pixel. By the way, manufacturers call them 4K and consider them as 4K.

Using the same principle on a tri-chip DLP, Digital Projection introduced the Insight 8k projector.
It is based on wobulation with a trip-chip DLP at 4k resolution. It looks great and it's likely that this example will be followed.
Of course, it uses a “proper wobulation” with an 8K source signal. There just a little downside with this resolution. For now, the required bandwidth for an 8K image cannot be generated or transfered on a single link. It will then requires to "slice" this image in four 4K quadrants.
We was using such techniques in the first times of 4K, so it is not a major issue. Just so funny that history repeats itself!

Figure 10 – Insight Laser 8K at ISE (courtesy of Digital Projection)

V. CONCLUSION

As a conclusion, we will not point the “best solution”. It does not exist and sometimes, some compromises have to be done.
We believe that it is important to be educated on which technology exist on the market to make the right choice for your project!

ACKNOWLEDGMENTS

The author thanks all manufacturers for their time to answer our questions and also all the talented R&D teams which bring all these technologies to us.

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W. Allen, R. Ulichney "Wobulation: Doubling the Addressed Resolution of Projection Displays”
Barco White paper “4K UHD explained”

Workshop: **Start Space Exploration with Space Robots (LEGO Mindstorms©)**

Elien Pludra ,Seppe Canonaco, Cosmodrome Genk-Belgium.

Our evolving society is in need of high-skilled scientists and engineers. Due to Flemish governmental policy, juveniles from 12 years old are encouraged to choose a scientific or technical education. For this, the communal offices of education supports schools and institutions who provide continuing education embedded in a STEaM -project (Science, Technology, Education, (Arts), Mathematics). This effort creates opportunities for science centres, astronomy clubs and planetariums for taking their social responsibility and organise science and technology workshops that not all schools can offer. Especially astronomy, which is a multidisciplinary science fits in perfectly.

The Cosmodrome of Genk (Belgium) organises several workshops for juveniles on astronomy, meteorology, aerospace, natural sciences etc. which needs handicraft with scissors, hammers, glue, etc... which stimulate their motorial capacities and know-how. A contemporary, educational and challenging tool is LEGO-Mindstorms©. Especially, Space Robots are an exciting topic who are simulating the robots on Mars. Using the classic building blocks and contemporary construction elements, motors, wheels, gears etc. as hardware which is connected to a “intelligent stone” which on its turn can be programmed by software. Programming (on PC/Mac or Tablet) has to be done with different, so called, programming blocks: Action Blocks, Flow Blocks, Sensor Blocks, Data Operation Blocks and Advanced Blocks by intuitive “Drag and Drop” and adjusting the characteristics of the blocks.

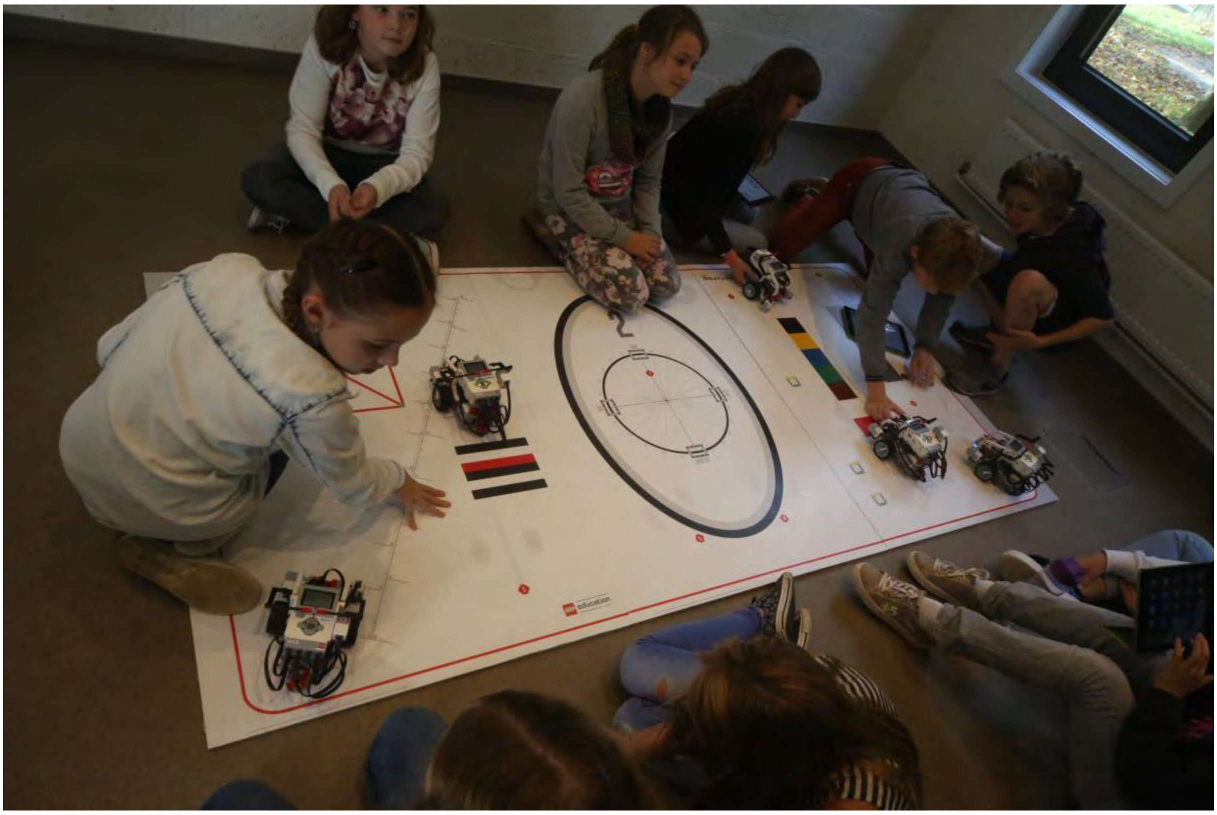
Mainly we use the robots on wheels exercising different tasks with their detectors. But you can build a setup for measuring the gravitational acceleration or even build a spectrometer! It has more applications than I can think off, it depends on your imagination and ideas.

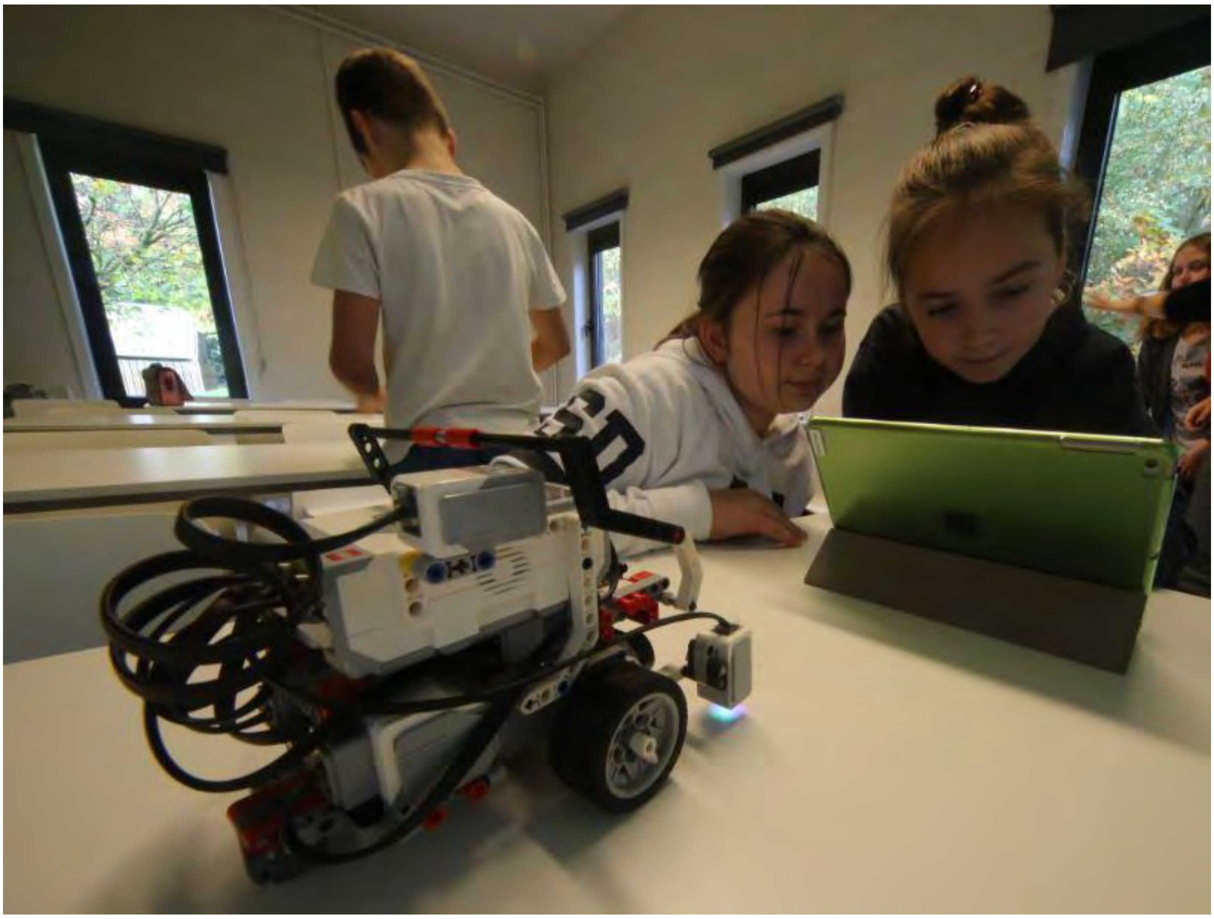
Our policy is to adapt/rename the workshops (when possible) and relate it to the theme of the (bi-)annual exhibition. In 2015, the theme "Beam Me Up" offered an exhibition on extra-terrestrial life, and the search for exoplanets, completed with the full-dome film “We Are Aliens”. And for more than twenty-five years, water rockets-centred workshops, which we renamed: the Flying Dino's in 2013 or Alien-Rockets in 2015. In 2019 we’ll go vintage, to the Moon-Rockets.

The workshop presents a demonstration with some exercises on the use of those robots using LEGO-Mindstorms©. Enjoy science and technology: the future is for the youth and the adults prepare the track.

See also: https://education.lego.com ; www.lego.com

www.cosmodrome.be
seppe.canonaco@genk.be





Programming the robot

Space Robots

Biography

I Mr.Dhananjay Raval am a Science activist and founder of ANKUR HOBBY CENTER at Ahmedabad for 35 years. We impart Science & Technology development programs for various age groups.

I have developed the only private planetarium in Ahmedabad India. We manufacture and develop Science kits on Astronomy, Physics,Chemistry,Biology,Geology, Aero modelling, electronics,etc.

Abstract

One of the students watching an astronomical film at our planetarium wanted to know that when the Big Bang took place there was vacuum, how could a blast be accompanied with sound then! In vaccum propogation of sound is not possible. Later I participated in the IPS-2014 in Beijing. There I had the opportunity to watch a few films. I noticed some scientific errors in the films .I discussed this with experts in the area and they confirmed the gaps.So, I decided that by IPS 2016 I would work on these errors and present my point of view on them.

Paper

DOME FILMS THROUGH MY EYES

Section 1.1

I run a Hobby Center in Ahmedabad since 1984 that is over 3 decades now. Science Education is indeed my Hobby. I have written numerous articles and books related to Science Education. I am the Secretary of a wonderfully working Astronomy Club. Sky watching, day time astronomy, model making and organizing India's biggest Astronomy festivals are the areas I work in. Seven years ago I had taken over the Ahmedabad Planetarium from the government of Gujarat and renovated the same. It has been recognized as the country's only Planetarium run by amateur astronomers. Even today its entry fee is just INR 15(0.21 USD)

Section 1.2

One Sunday students and teachers had about the birth of galaxies. There is always a mention of the Big Bang in those films. During the display of the Big Bang in most films a blast is generally shown on screen. At that time parallaly a LOUD SOUND is also heard. It is interesting and thrilling to watch the bang and hear the ear piercing sound. With the help of animation within come to visit the Planetarium. They had taken a prior appointment to see me. After the film the question answer session began. One of the students asked me that many astronomical films talk 15-20 seconds the Big Bang, the making of the galaxies and the solar system is all shown. He wanted to know that when the Big Bang took place there was vacuum so, how could a blast be accompanied with sound then! In vaccum propogation of sound is not possible.(See Photo 1)

Photo1 :Screen shot of the Big Bang accompanied by sound –Who heard it?

The idea of writing this paper came from the question put across by this child. The students question made a lot of sense. Everything that a child is curious about or would want to know is not always found in text books. For that they need to go to libraries, visit Science centers or planetariums. Here they are sure they would find answers to questions that are out of syllabus. At that time if SUCH ERRORS are found in the learning exposures given at planetariums or Science centers is not acceptable. Thus required previews and reviews of every film shown there must be taken. The role of a Planetarium Director becomes very important here. Such questions need to be thought of sincerely and discussed with the audience with immense openness to work out a solution to the question. The objective behind presenting the paper on this platform is just this. Since Planetarium Directors, filmmakers, script writers and people working in various areas from all over the world gather here at one platform –questions like these if raised here would make future work in this area made better.

<u>SectionII</u>

One more such error was noticed in the film **Back to the Moon for Good**. We were working on dubbing the film in Hindi and Gujaratilanguages. Thus we got to watch the film several times. A very beautifully made film was seen for the first time at IPS 2014 - Beijing. It received several awards during the IPS 2014.We had the good fortune to meet the film makers of this film too. There is a scene in this film which shows APOLLO and LANDER 40 years ago. Both astronauts shown in the film move on the land of the moon and then are seen boarding the LANDER gain. Now when the LANDER takes off again a blast is shown. Sand, mud, and stones are shown flung . But at that time the American Flag is shown unmoved! When in reality it had fallen off. (See photo 2)

<u>Photo2: When LANDER of Apollo 17 takes off-Sand, mud, and stones shown flung but the American Flag unmoved!</u>

In most Astronomical Films our Solar System is shown .At that time the planets moving around the Sun are shown moving in elliptical orbits. The orbits undoubtedly are elliptical but not as drastically elliptical as shown. By and large the scene depicting the Solar System is shown by a side view rather than the top view which makes the orbits look indigestibly elliptical.(See photo 3)

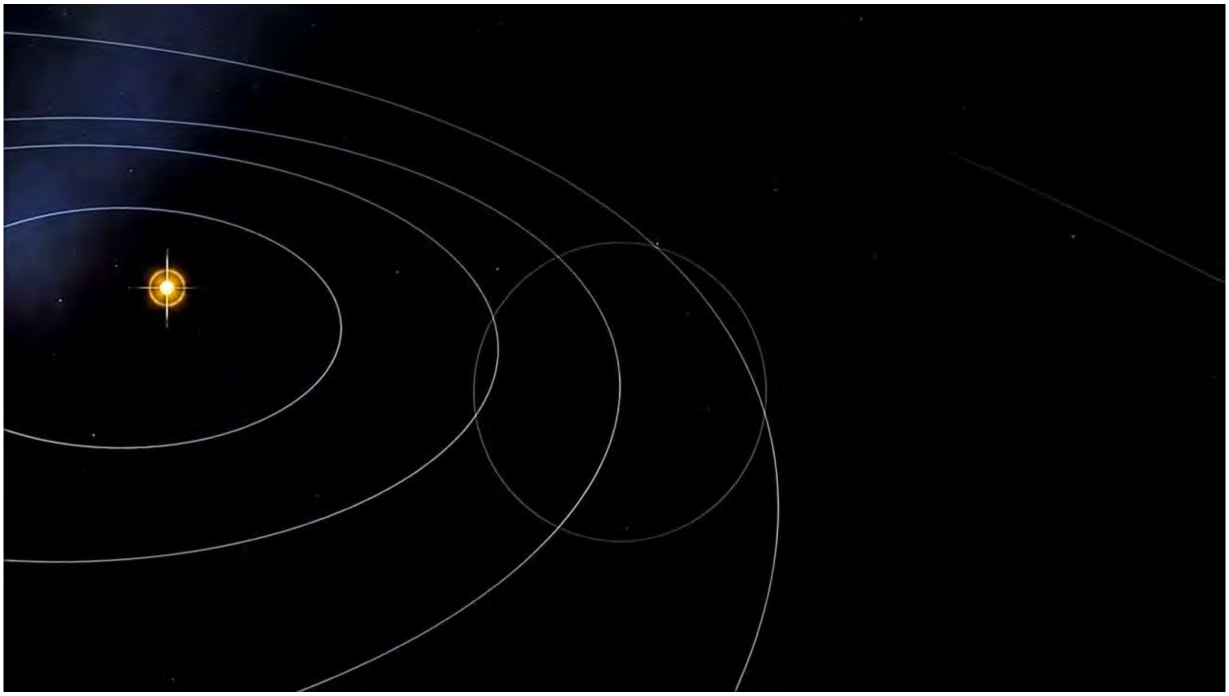


Photo 3:Most astronomical films show orbits very elliptical.

This made me think that while making a planetarium film 2 things need to be kept in mind:

What does a common man want to know through these films or what would be the topic of immense interest which a viewer would both want to learn and enjoy from.

For this a larger than life element should be included by all means but it should never be done without deep involvement and consultation of subject experts.

In 2016 we had taken up the making of an Astronomical Film as a Pilot Project. As subject experts we invited Senior Scientists from prestigious institutes -ISRO and PRL. In our planetarium we surveyed for 3 years as to what people would want to know or learn about?

Feedback given by students, teachers and common man made us decide what elements or topics we could cover in our film. What would make more and more people visit the planetarium was also kept in mind during the making of the film. We included two characters in the film-Grandfather and grandson.

During the production we noticed that we rarely or never found a grandfather and grandson visiting the planetarium. By and large we had fathers and sons or daughters visiting it. So we replaced the grandfather from the script with father.

Whether a film is made well or not is decided only after it is made. Whenever we screened our film it got an overwhelming response. On many occasions we found children thanking their parents for giving them an opportunity to watch the film. Two things that were really appreciated about our film were-

The characters of the film which let the film keep going are never seen on screen and certain astronomical facts were stated in film directly by prominent scientists of India. All these scientists shown in the film were the ones who people are crazy about meeting. Through this pilot project of ours we realised what were the key ingredients to the making of any astronomical film. We sent this film for the 7th Science Film festival for nominations. 190 films were nominated for this film festival of 2017. 10 films out of these were short listed for awards. This film COSMOS which was our First Production was SHORLISTED!

ACKNOWLEDGEMENTS

Thanks to Dr JN Desai Senior Scientist PRL Ahmedabad who endorsed our findings and our curious viewers at the Planetarium whose questions made us think and prepare this paper.

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Films

1.Back To The Moon,

2.COSMOS

DOME FILM THROUGH MY EYES

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Article by

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A Simple Audience Feedback System for Show Evaluation

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BIOGRAPHIES

Morgan Rehnberg is the Museum's Director of Scientific Presentation.

ABSTRACT

The Fort Worth Museum of Science and History has developed galleryRate, a freely-available, open-source, touch-enabled application for simple guest surveys. I provide an overview of galleryRate and describe its use in the Noble Planetarium to evaluate our shows and live presenters.

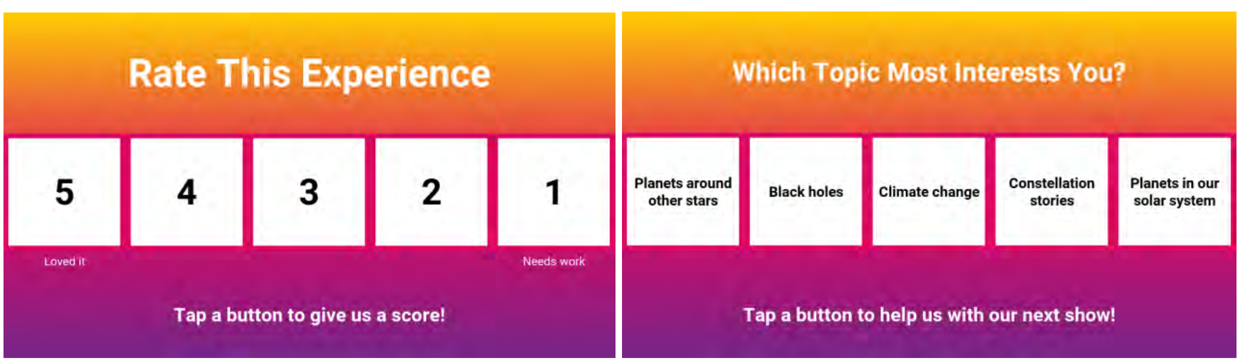
INTRODUCTION

The planetarium is an inviting, often awe-inspiring environment for many guests. This general aura of wonder can often overwhelm viewers' other feeling about the quality of the presentation in ways that may be difficult to ascertain. The end result is an experience that may be superficially satisfying without a lasting educational effect.

The key to understanding how this phenomenon affects your planetarium is a rigorous and vigorous evaluation of every show. Professional, in-person evaluation can be a time-consuming and expensive endeavor, which limits the organizations capable of undertaking it. In this paper, I present a simple, free, cross-platform, open-source software tool called galleryRate [1]developed at the Fort Worth Museum of Science and History and deployed in the Noble Planetarium therein. It enables consistent collection of a range of data and easy operation for frontline staff and managers alike.

AN OVERVIEW OF galleryRate

galleryRate is a touch-first graphical application developed using the Kivy Python framework. It is compatible with Windows, macOS, desktop Linux, and Android, although the lack of a touchscreen limits its utility on macOS. A simple text-based configuration file enables users to define a question to be asked and five responses for guests to choose from. The appearance of all onscreen elements can also be customized. Here are two potential screens illustrating the range of audience feedback that can be collected.



Button presses are collected and written to file once a minute. By specifying the output location to a cloud synced folder like Dropbox, real-time results can be remotely monitored. A timestamp is included for each write, enabling

[1] galleryRate is available for free here: https://github.com/FWMSH/galleryRate

easy matching with a given show. It is even possible to determine votes made by audience members who left the show early, depending on where the voting screen is installed. For more accurate data collection, only one press is registered per second to help defeat "button mashing."

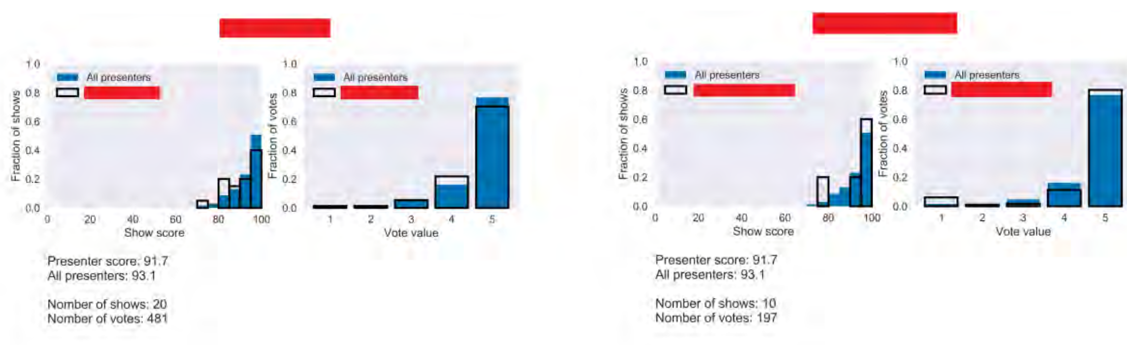
USING galleryRate IN THE NOBLE PLANETARIUM

The Noble Planetarium currently uses galleryRate for the evaluation of planetarium shows and planetarium presenters. At the conclusion of each program, the presenter invites guests to leave a rating for the show, which is then correlated with the show's name, time slot, and presenter. Because our voting screen is mounted within the dome, audience members who depart early (and thus may be more dissatisfied) do not have the opportunity to vote. This is, however, an unusual circumstance.

Raw votes are converted to what we term the "show score." A five-star vote awards five points, a four-star vote, four points, etc. This is divided by the five times the total number of votes and converted to a percent. For example, a show with 4 fives, 3 fours, 0 threes, 1 two, and 0 ones would have a show score of 85%, which can roughly be interpreted like a classroom grade. Since not every guest elects to vote, the number of votes (often greatly) undercounts the number of sold tickets.

The data indicate that our live-presented shows (average score: 95%) are generally more popular than our playback shows (average score: 87%). Live shows also have a smaller spread in scores, indicating that the guest experience is more consistent in a live show than a playback show. This could be because, for example, a live presenter is better able to tailor their content for the demographics of the audience. As mentioned earlier, *all* planetarium shows tend to be popular with guests, making it difficult to distinguish true differences from statistical noise.

To evaluate presenters, we use two primary metrics. The "presenter score" is computed like the show score and aggregates all the performances of a given presenter for a given show. We also use the distribution of individual show scores and votes to reveal additional detail. This helps clarify *how* a presenter earned a particular presenter score. For instance, a presenter score of 80% could result from 20 shows each with a show score of 80% or ten shows with a score of 60% and ten with a score of 100%. Those two cases would likely represent very different situations. The below charts of actual presenters illustrate such a situation:



The left presenter[2] is what I might consider a "middle of the road" presenter. Their show score distribution generally follows the average trend. The right presenter is more "boom or bust," earning a disproportionate number of five-star ratings, but also an unusually large number of one-stars. The presenters have identical presenter scores, but I would mentor them differently.

It is worth noting that we do not make retention decisions solely or even primarily based upon the show rating system. Direct observation of staff performance, enthusiasm, and commitment are more important in evaluating the

[2] Names obscured in red for privacy

success or failure of a given individual. However, we have observed a qualitative correlation between the perceived quality of a presenter and their presenter score.

SUMMARY

Quantifying the performance of a show or presenter is a critical contribution to data-driven decision making. It enables an organization to test their implicit assumptions and gives the audience a hand in improving their experience. The ways the Noble Planetarium has used a generalized voting system thus far have been basic, but we look forward to deeper applications. Applications we are considering include evaluating the effectiveness of a marketing campaign, soliciting suggestions for new programing, and performing "post-test" analysis of knowledge retention.

Automatic audio positioning for 3D live concert

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BIOGRAPHIES

Dipl. Ing. René Rodigast is business manager, sound designer and consultant for spatial sound systems in the acoustics department at Fraunhofer IDMT. In his role, he successfully acquired and managed 3D audio installations for live events and planetaria (Jena, Hamburg, Kiel, Bochum, Berlin)

ABSTRACT

Since 2014 the university of applied sciences Kiel is using an object based 3D audio system (SpatialSound Wave) in their full dome theater Mediendom.
The composer and guitarist Jens Fischer came up with the idea and concept for a music show that takes full advantage of object based 3D audio.
He is playing live in concert together with musicians that are pre-produced in audio and video. The musicians are placed in a virtual environment created by Bob Weber, that has been pre-rendered with 3D animation software to a full dome video. The goal was to find automatic way to position the 3D audio objects in relation to the video objects displayed in the 9 meter dome.

INTRODUCTION

Since the installing of object based 3D Sound system SpatialSound Wave (SSW), the Mediendom Kiel is using the possibilities of free positioning sound objects in the dome together with video. In the past different interfaces between object based sound and playout video objects was tested and adapted. In the Mediendom a free programmable user - and controlling interfaces based on Evans&Sutherland Digistar 5 [1] was used. To exchange metadata of the planetarium´s video system Digistar 5 with external units and specific with the 3D sound system lot of adaptions and tests were done. The combination of object based audio and video is used in daily shows. The first 3D music live show together with synchronized full dome content was done in the planetarium Jena in 2016 with the German pop band Staubkind. The first interactive live music show was created by the musician Jens Fischer and the 3D-artist Bob Weber in collaboration with the team of the Mediendom Kiel. An adaption of the Spatial Sound Wave interface was done and used for a full integrated live music and video show by using interactive controlled audio objects. This first interactive live concert miRatio took place in spring 2017.

I. BASICS

I.1 Basics Spatial Sound Wave

The 3D audio system SpatialSound Wave is developed from Wave Fields Synthesis. With a reduced amount of loudspeakers with greater distances between them and the enlargement to the 3D space the efficient object based sound system was developed by Fraunhofer-Institute Digital Media Technology (IDMT). Like in wave field synthesis systems the psychoacoustic perception of point sources or plane waves is possible by localization accuracy for a listening area by the absence of a sweet spot. The audio renderer is fully adaptable to the different necessities of the user. It is configured joining together different elemental audio blocks like filters, equalizers, delays or gains to create a complex processing chain called graph. The rendering framework also provides a message subsystem to send and receive control data from the audio block as well as to control the external messages received via the network interface. Though the implementation of the message subsystem does not require the use of any specific communication protocol, the actual implementation relies on the OSC protocol [2] because of its intuitiveness. The communication and interfacing between the sound system SpatialSound Wave and the full dome video system Digistar 5 for the 3D interactive live sound show miRatio was programmed based on the OSC communication.

I.2 User Interface

SpatialSound Wave (SSW) is a browser-based graphical user interface that allows an intuitive control of SSW-Systems in various use cases. SSW comprises several apps, designed to perfectly fit distinct use cases such as the “LiveApp” the “DemoApp” the “Sessionplayer” and the “ProductionApp”.

The server hosting the apps is part of the renderer unit. A connection to a (local) network provides access via clients such as PC, Mac, tablet or smartphone [4]. Also exchanging meta-data between SSW and external devices can done easily by the OSC protocol. This application is running in the Mediendom Kiel. There the SSW user interface is used parallel to the UI of the Digistar 5 Planetarium System. In the Digistar system the audio tracks will select and positioned in time. Hence the audio objects can coupled to the video objects in the Digistar 5 software on the using of media objects (audio, video, metadata) is easy to handle in the common planetarium system environment.

I.3 Hardware environment

A typically playout system by using SSW [4] is showing in figure 1.

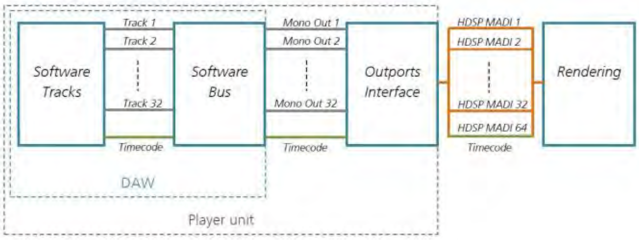

Figure 1: typical system structure for Spatial sound wave rendering

For the miRatio concert the video playout system and live signals must integrated in the system. Also synchronization and clocking was integrated in the hardware environment. In Figure 2 the block diagram of the miRatio hardware is shown.

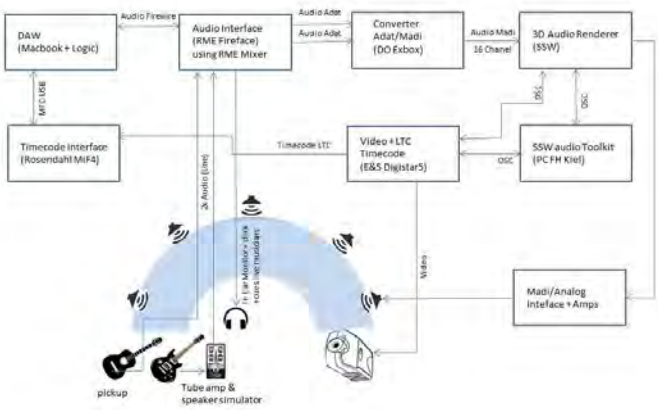

Figure 2: block diagram of the 3D audio system during the miRatio concert

II. LIVE 3D MUSIC SHOW

II.1 Artistic workflow

The starting situation for a typical full dome production is the dome master of the movie, the sound design and the soundtrack composition here as a 16 multitrack mix down project including the live inputs coming from the guitars. The dome master (see figure 4) is a version of the movie in a flat, circular shape (disk), which is later stretched and projected into the dome. The dome master provides the opportunity to watch the movie on a screen and the producer is still able to coordinate the directions the way they are meant to be in a dome. During the mix down, any kind of effects and automation can be used in the DAW [4]. In opposite to this conventional way to produce 3D sound for dome in the production of miRatio a much easier way was done: The producer came with the recording session into the dome and made all the mix and FX tunings directly in the dome together with the positioning of the audio objects. Thereby the 16 channel multitrack down mix was the base for the spatial sound production. Each mono track represents one object that was freely positioned. With pure audio data and the object positions related to the production space at the Mediendom Kiel the productions now can be exchanged and played back in different locations using SSW. The show was also tried to be played in the Zeiss Planetarium Jena at the 11th Jenaer Fulldome Festival but had to be interrupted 6 times because of synchronization-problems between video and audio (see chapter below: Experience in the dome). It is available for SSW equipped planetariums under the condition of a reliable timecode-connection between the video- and audio-system. A listening test on the reproduction system is always recommended to be sure the mix has been scaled as expected. If the result of the automatic scaling algorithm is not satisfying, the session has to be scaled manually. While different scaling factors can be tried out for the X or Y axis, the Z one is always restricted to the height of the screen to avoid the parallax effect [5].

II.2 Production workflow

The production workflow of miRatio is not generally different to conventionally audio productions. The audio tracks of the instruments (flute, drums, piano, cello, bass marimba and more) were recorded in studio environment and pre-produced. The instruments are recorded individually without cross talk to other instruments. Also the related video clips are recorded separately for each musician in a real stage environment at the legendary “Lutterbeker” live stage in Lutterbek/Schleswig-Holstein. All positions of the video clips are calculated in relation to a virtual camera and later adapt to the positions of the audio objects. Therefore new software was written by the authors (2). The pre-produced tracks (with Apple´s Logic Pro Digital Audio Workstation) was played out while the concert. The synchronization to the video was done by an external timecode-signal (LTC) coming from the video system (Digistar 5) and converted to midi-timecode into the DAW. Now all the audio tracks (playback and live-guitars) stand by as audio live stream by MADI digital audio format. This stream was rendered in real time by the SSW Audio processor to the 3D audio speaker setup in the dome. Position information for the audio objects are calculated externally by the SSW toolkit software (descripted below). Thereby the SSW system scaled automatically the pre-calculated positions of the video clips (musicians) to the audio objects. For visual control of the video to audio converging, in the Digistar 5 video system some extra video objects was generated. This video objects was shown as loudspeaker symbols in the dome and was moved together with the connected audio object exactly to the position of the related video clips. The visual video audio convergence is shown in figure 3 in the dome master view.

Figure 3: speaker symbols coupled with audio objects for visual control of the sound position

Now the main task of the external software SSW toolkit was to adapt the video object positions to the positions of the audio objects related to the respective video frame and timecode.

II.3 The idea behind miRatio

In the fulldome live concert miRatio a live musician plays live together with musicians they are virtually showed as video in the dome.

The individual single tracks of the musicians shown in the video will summed with the live instrument played originally on stage in the dome. All the tracks and sound effects was mixed in an external Digital Audio Workstation (DAW) and merged to 16 audio channels and streamed to the SpatialSound Wave 3D audio system. In the 9m diameter Mediendom of the University of Applied Science Kiel this 16 audio sources was positioned in the dome together with the equivalent video of the musicians and background video. That means these musicians will exactly acoustically realized where they are visible in the video. In this constellation the audio and the video must be exact synchronized and frame accurate.

In the live music show “miRatio” a concert with 7 musicians should celebrated. The lineup of the musical ensemble is guitar (live), piano, marimba, cello, flute, bass, drums and „Ondes Martenot". The live musician Jens Fischer should play in the middle of the dome with acoustical and electric guitars in a sitting position. His 6 musical colleagues should places virtually in the dome together with a live rendered video and object based audio (the dome view is showing in figure 4). The position of the musicians will move continuously depending on the part of the concert. The SpatialSound Wave System should play the sounds in the right position related to the view of the musicians. The live sound of Jens Fischer will played synchronous to the other six instruments on static or changing positions.

Figure 4: domeview to the “miRatio” ensemble

II.4 Implementation

Before the show was produced the music videos and audio tracks of all single musicians were recorded individual in the studio. For a realistic live show in the dome it is very important to bring the acoustical image together with the video because of the realistic inclusion of the audience [3] By the dome show the position of the music video was known. This positions of the 6 musicians over the whole show was exported as readable meta data (x,y,z,time,…). In the new software (SSW toolkit) the positioning data of the music videos was converted to spatial sound wave meta-data (positioning data for SpatialSound Wave). The positioning data was inserted in a prepared SpatialSound Wave session. After that the SpatialSound Wave Session was saved and imported to the SSW Audio Renderer.

For the compilation of positioning data in Cartesian format usable in the audio renderer from the positioning coordinates in pixel format usable in the video production environment (Adobe´s After Effects) a standalone software (SSW toolkit) was developed by the Mediendom Kiel programmer.

The converter so called “SSW Toolkit” developed in C# with Microsoft Visual Studio 2015 was designed to read and convert the positioning coordinates and synchronize it to timecode. In Figure 5 a screenshot of the SSW Toolkit is shown.

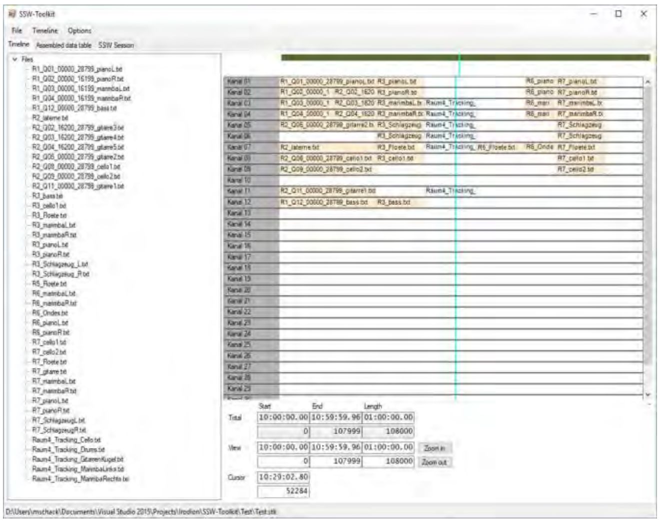

Figure 5: screenshot of the SSW Toolkit converter

The full concert consists of seven scenes, called “rooms”. In every room we have different instruments and positions. Each room was developed independent with animation software. As a result, we had chunks of data for every instrument and scene, which need to be adjusted in the final time line. Du to different production methods, we also had two formats of data:

The Cartesian positioning coordinates was available in following format:

0:[1.40435,3.82856,11.2145]
1:[1.40435,3.82852,11.2145]
2:[1.40435,3.82842,11.2144]
3:[1.40435,3.82824,11.2143]
…

In opposite the positioning pixel coordinates (usable in After Effects) was available in following formats:

0:[174.75,144.625]
1:[174.75,144.625]
2:[174.75,144.625]
3:[174.75,144.625]
…

Therefore we also created some simple time line editor in the SSW-Toolkit. The workflow to convert the positon data to a session readable for the SSW-system was like this:

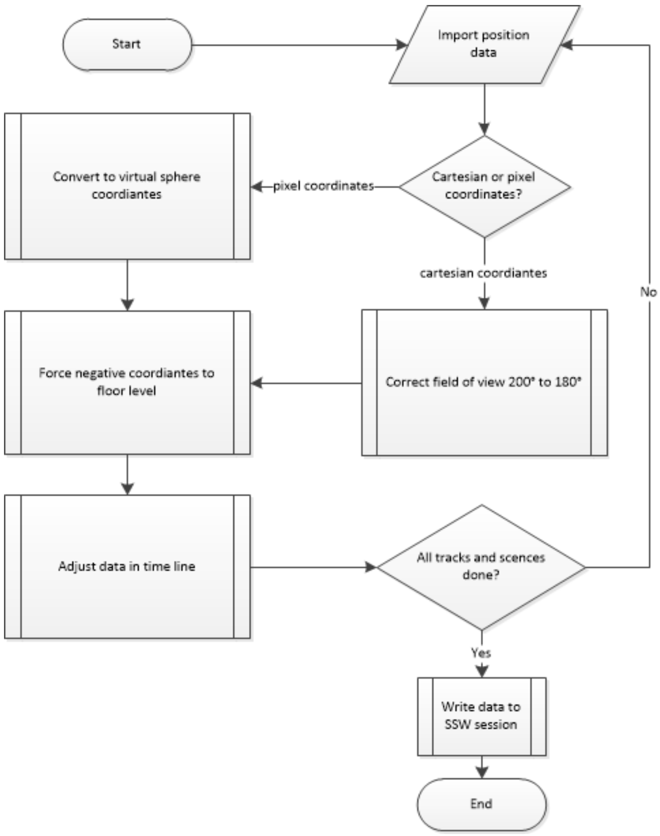

Figure 6: workflow in SSW-Toolkit

The created session file was copied to the SSW-Renderer-PC auf then loaded with the SSW-ProduktionApp. Then all audio source are located at the positions of the visible instruments in the virtual rooms. In the new software release 3.0 of SSW this could be nicely seen in the 3D view.

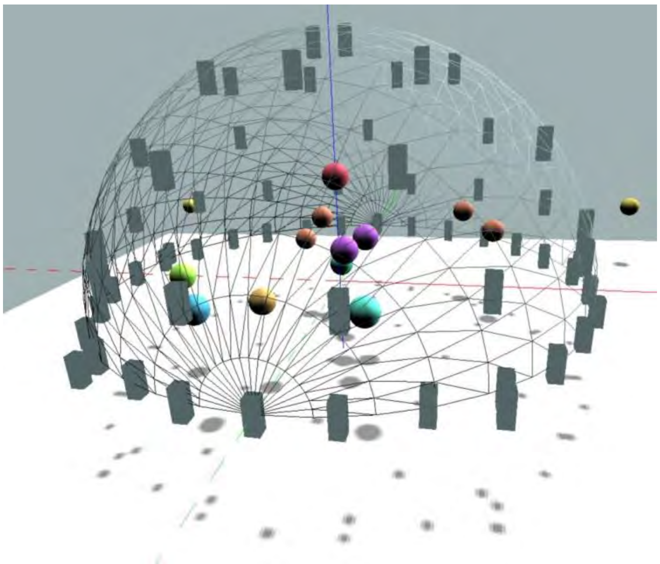

Figure 7: scene in 3D view of SSW-ProductionApp

II.5 Experience in the dome

While video and audio played out from the same system (here the E&S Digistar5) this is normal for conventional full dome shows. The situation is changing as soon as external audio systems must play the audio files synched to a full dome movie by a timecode.

In the miRatio concert the video system is working as timecode-master and the audio system in slave-mode.

In this connection it is necessary to evaluate the time code in each system permanently. Systems who read a starting point from a time code signal at once by the starting point and then running free in parallel are not suitable. That is uncritical in planetarium shows with abstract graphical pictures they are not just related to the sound. As soon as acting people like musicians or artists involved in the show and viewed by the audience a continuous frame accurate synchronization is required. Also by play out of sound synchronous pictures like speaking people, impacts, steps, and others this frame accurate synchronization is necessary.

The videos for “miRatio” were created to be played with exact 30 fps. But due to slight different projector update rates some systems play the video corrected to this update rate and just correct the audio. Since we get the audio from an external DAW, this is not possible in this production.

The Digistar 5 system at the Mediendom Kiel could be configured to play exactly frame synchronous to the external audio by adapting the frame rate of the video projectors to the internal video player [6]. But we found no way to let the fulldome system at the Planetarium Jena play the videos in sync, so we had the split the concert into the seven rooms and started each room separately.

ACKNOWLEDGMENTS

Many thanks to Jens Fischer and his musicians for great playing and adapting music to 3D live environment in the Mediendome Kiel. Also many thanks Eduard Thomas for supporting this project.

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[6] homepage Jens Fischer, URL: http://jensfischer.de/miratio-technik/

From research to your dome: Data2Dome, an open-data dissemination system for planetarium content

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BIOGRAPHIES

Max R. Rößner is a PhD electrical engineer and has been working in the planetarium field since 1996. At the European Southern Observatory (ESO), he was responsible for the design, integration and commissioning of the projection and multimedia system of ESO's planetarium, and now is for its technical operation and maintenance.
Lars Lindberg Christensen is a science communication specialist and Head of the education and Public Outreach Department (ePOD) of the European Southern Observatory in Munich, Germany. He leads public outreach and education for the La Silla Paranal Observatory, for ESO's part of ALMA and APEX, for the European Extremely Large Telescope, for ESA's part of the Hubble Space Telescope and for the IAU Press Office.
Mathias André obtained an MSc in Computer Science in England and worked for several years as a Unix system administrator and IT Operations Manager before joining the ESO outreach group to tackle new challenges as Web and Advanced Projects Coordinator.

ABSTRACT

Astronomy is a dynamic discipline, with new scientific findings and data being published every day. Audiences expect planetariums to address such news and discoveries in their daily planetarium programming. The Data2Dome (D2D) project implements a technical standard with which to stream newly released content and metadata from astronomy research organizations and space agencies directly into fulldome planetarium systems – without any need for time-consuming manual data shuffling and processing. In this way, the technical boundary between astronomy research and planetarium programming is bridged, enabling planetarium operators to swiftly offer up-to-date content to planetarium audiences. In this paper, the system's architecture and the interface standard are introduced and the possibilities the interface offers are demonstrated.

INTRODUCTION

The European Southern Observatory (ESO) opened its Visitor Centre, located at its Headquarters in Garching bei München, in April 2018. The centre's planetarium features a 14 m, inclined dome, seating 109 visitors. As a research organization, ESO is particularly interested in featuring latest scientific results in the day-to-day planetarium programming. Ideally, a planetarium show would be updated on a daily basis, as new scientific findings are published. Planetarium system vendor Evans & Sutherland, the International Planetarium Society, and ESO collaborated on the development of a data standard to implement such functionality: Data2Dome. It is an open standard – other planetarium system vendors and data providers are invited to implement this standard in their planetarium software packages and data distribution systems, respectively. This article summarizes the basic concepts of the data interface. The complete specification document [1] is available on www.data2dome.org.

I. DATA SOURCE: THE SERVER SIDE

Data2Dome describes a data-driven content distribution system. It defines a standardized way for data providers to publish their outreach and informal science education offerings. By implementing the Data2Dome publishing standard, organizations can provide content directly to planetarium operators around the world. This content is published and provided in a way that is directly compatible with digital planetarium software.
Data providers are recommended to use a free and open licensing scheme for data distributed through D2D. The presenter in a planetarium should not have to bother with the exact terms and conditions for any individual asset. For example, ESO employs

the Creative Commons Attribution license, which basically states that users can do anything they wish with the data, as long as ESO is mentioned.
On a technical level, Data2Dome is implemented as JSON data feeds. These are URLs that respond with text data formatted using the Javascript Object Notation standard [2].

I.1 Meta Feed

An organization willing to provide material through the D2D scheme first implements a Meta-Feed. A Meta-Feed provides general information about the data provider along with a list of all the various payload feeds that the provider offers. Thus, the URL of the Meta-Feed is the only piece of information a planetarium software package needs to be provided with to access this data supplier's resources. As an example, ESO's D2D Meta-Feed is accessible on http://www.eso.org/public/d2d/. It provides ESO's contact information, the logo used to visually identify a provider in the target software packages, and a list of the URLs of the payload feeds ESO offers, along with a brief description. One of the payload feeds in this example is the "Portal to the Universe" news feed. The Meta-Feed specifies the URL https://www.portaltotheuniverse.org/d2d/news/featured/ for this resource:


```
Creator:            "European Southern Observatory"
URL:                "https://www.eso.org"
▸ Contact:          {…}
▸ Logo:             "https://www.eso.org/publ…edium/eso-logo-p3005.jpg"
▾ Feeds:
  ▾ 0:
    ▾ URL:          "https://www.portaltotheuniverse.org/d2d/news/featured/"
      Type:         "News"
      Name:         "Portal to the Universe"
      Description:  "Portal to the Universe"
  ▸ 1:              {…}
  ▸ 2:              {…}
  ▸ 3:              {…}
  ▸ 4:              {…}
```


Figure 1 – ESO's D2D Meta-Feed, as delivered through http://www.eso.org/public/d2d/

Other D2D feeds ESO offers (hidden above for clarity) are an astro-calendar event feed, image, video and 3D model feeds, and a planetarium music feed.

I.2 Payload Feeds

When accessing one of the payload URLs provided is the Meta-Feed, a JSON file that holds the actual information is sent back. To limit the file size and, hence, realize quick response times even when used through low bandwidth connections, long lists can be split into multiple pages. In the example below, 11721 items are provided in the D2D feed, spread over multiple pages. The "Next" tag provides the URL for the subsequent page.
The assets of one particular feed item are bundled in a collection. A collection is a group of related assets. One can consider collections representing a "Press Release", an "Event" or just a single media item such as a historical or astronomical photo. A collection might, for example, include one or more images, a diagram, a video, and possibly even an audio file containing spoken narration. The video might be provided in both flat and fulldome form. There may be multiple image resolutions, or there may even be flat and fulldome versions of an image. Along with all these assets, there is a written description of the event or release.
Note that image, video and other files are not bundled in the collection. Rather, a link is provided that points to this resource, stored somewhere else on the internet. In this way, it is not necessary for the planetarium system to load and store all items, resulting in massive storage needs. Rather, the assets can be loaded onto the planetarium system only when requested by the planetarium lecturer.
In the example below, taken from ESO's "Portal to the Universe" D2D feed, one can see this concept visualized in a structured way. A collection has, among others, tags for the data creator, a reference URL pointing to a human-readable web page, the publication date, the title and the description. The description can be formatted as an HTML markup page. In the case of this example, resource #0 is an image specified by its URL and the preferred projection onto the dome. In this case, the projection is "Tan", meaning a flat, rectangular image intended for viewing as a billboard in 3D space (equivalent to a slide projector projecting onto the dome). Obviously, other common projections, like fisheye or equirectangular, are specified in the standard as well.

```
Type:                   "News"
Count:                  11721
▶ Next:                 "https://www.portaltotheu…2d/news/featured/?page=2"
▼ Collections:
  ▼ 0:
      ID:               "640408"
      Feed:             "NASA's Goddard Space Flight Center"
    ▶ ReferenceURL:     "http://www.nasa.gov/imag…axies-and-homeless-stars"
      PublicationDate:  "2018-06-15T13:16:00"
    ▶ Title:            "Hubble Captures Cluster …xies and Homeless Stars"
    ▶ Description:      "<p><span>This sparkling …ope to study.</span></p>"
      Credit:           ""
      Creator:          "NASA's Goddard Space Flight Center"
      Contact:          {}
    ▼ Assets:
      ▼ 0:
          MediaType:    "Image"
          Credit:       "ESA/Hubble &amp; NASA, RELICS"
        ▼ Resources:
          ▼ 0:
              ResourceType:   "Original"
              MediaType:      "Image"
            ▶ URL:            "https://www.portaltotheu…/original/pttu640408.jpg"
              FileSize:       112819
            ▶ Dimensions:     […]
              ProjectionType: "Tan"
          ▶ 1:                {…}
          ▶ 2:                {…}
          ▶ 3:                {…}
          ▶ 4:                {…}
  ▶ 1:                  {…}
  ▶ 2:                  {…}
  ▶ 3:                  {…}
```


Figure 2 – Portal to the Universe Feed (page 1), as delivered through https://www.portaltotheuniverse.org/d2d/news/featured/, cropped after collection #3 for clarity.

In ESO's implementation, the JSON feeds of the D2D offerings are generated by the content management system also feeding ESO's websites, media kiosks in the exhibition area of ESO Supernova Visitor Centre, and the planetarium ticketing system. With all these systems hosted under a common umbrella, the D2D feeds are created and disseminated automatically, without the need for much user interaction.

II. DATA SINK: PLANETARIUM SOFTWARE INTEGRATION

The amount of assets delivered through a D2D feed can be massive. As an example, ESO's "Portal to the Universe" feed illustrated above has 11721 items (as of June 2018). Therefore, system designers implementing support for Data2Dome feeds are encouraged to implement easy-to-use systems for searching, browsing, sorting, and accessing the data collections and their assets. Wherever possible, previews and thumbnails should be used to help planetarium presenters quickly select appropriate media. Every effort should be made to reduce the effort of selecting, downloading, and displaying Data2Dome resources.
Provider branding should be respected. Use provider logos and contact information where appropriate.
Respect credit and licensing information – and make it easy for the planetarium presenter to find this information. All ESO-produced material is published under the terms of the Creative Commons Attribution license, but D2D is not restricted to this scheme, so other data providers might wish to apply a more restrictive license.

D2D is compatible with the Astronomy Visualization Metadata Standard (AVM), described elsewhere [3]. AVM specifies tags in the file header of image files, such as the wavelength the image was taken in, and its position, orientation and size on the sky.
Figure 3 shows the implementation of D2D in the Digistar 6 software package by Evans & Sutherland. Data 2Dome content is displayed alongside other data sources, such as Digistar's native astronomical database, user-created content, and content provided through the Digistar Cloud Library. It can be sorted in a table similar to a file list view. It is also integrated into the system-wide search functionalities. By selecting an asset, the presenter is provided with a descriptive summary of what the asset illustrates. Once downloaded (by clicking on the "cloud" icon), an asset is automatically delivered to the graphic processor PCs and can be brought to the dome by a simple drag-and-drop procedure. In this way, a planetarium presenter can quickly inform himself about the news that were published during the previous night, and include such content into the planetarium presentations of that day by a few clicks: The show is kept up top date on a daily basis.

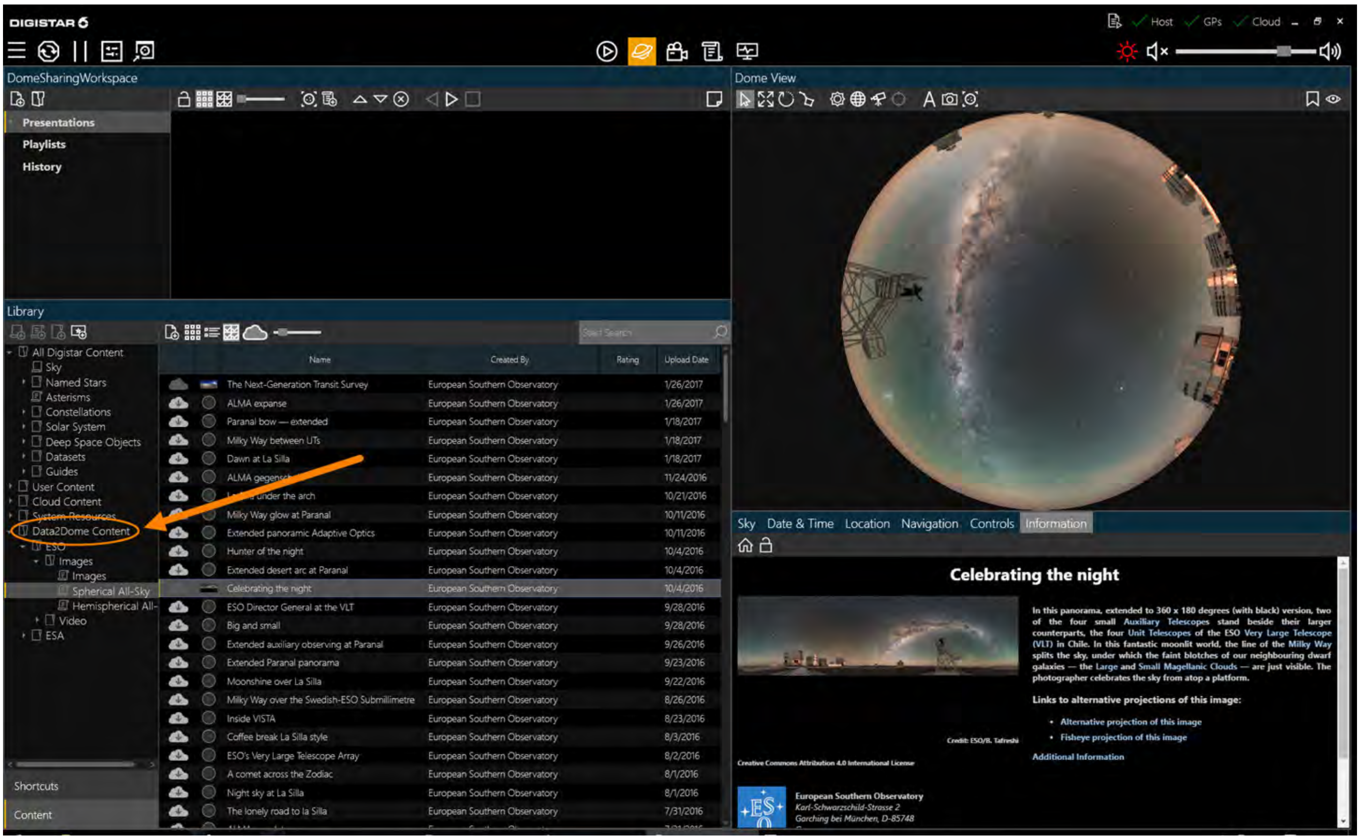

Figure 3 – Data2Dome implementation in Evans & Sutherland's Digistar 6

As of June 2018, the authors are aware of further Data2Dome implementations in DigitalSky Dark Matter by Sky-Skan, and Shira Universe by SureyyaSoft. Other planetarium vendors are invited to join this community effort.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the collaboration with Evans & Sutherland, the International Planetarium Society, and many individuals on the Data2Dome project. Particularly, may thanks to Kevin Scott and Kevin Teynor (Evans & Sutherland), Jürgen Rienow (Berlin Planetarium), Björn Voss (Münster Planetarium), Mark Subbarao (Adler Planetarium), Ka Chun Yu (Denver Museum of Nature & Science), Marta Entradas (London School of Economics and Political Science), Robert Hurt (Infrared Processing and Analysis Center), Ryan Wyatt (California Academy of Sciences), and the IPS Science and Data Visualization Task Force.

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Building a planetarium with research data in mind: the case of Strasbourg's University

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BIOGRAPHIES

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ABSTRACT

Context. The Planetarium of Strasbourg, depending on the Garden of Sciences, is currently the only university planetarium in France. Moreover, it maintains close links with the Strasbourg Astronomical Observatory, its parent structure from 1986 to 2008.
Aims. The proximity encourages us to develop education and public outreach practices closely related to the academic research done at the Observatory that would benefit both sides.
Methods. We propose to use the Hierarchical Progressive Survey (HiPS) scheme for describing astronomical data as a practical solution to build bridges between research and planetariums and to advance further the issue of streamlining the process of going from data to dome.
Results. We give some insights about how the implementation of HiPS into planetarium simulation software could be done through the Aladin Fisheye prototype and the HiPS clients currently available.

INTRODUCTION

The Strasbourg Astronomical Observatory is an Observatory for Universe Sciences, an internal school of the University of Strasbourg, and a Joint Research Unit (UMR 7550) between the University and the National Center for Scientific Research (CNRS). The Observatory hosts the Strasbourg Astronomical Data Center (CDS), which is dedicated to the collection and worldwide distribution of astronomical data and related information.
The CDS harbors three major services: the astronomical database SIMBAD which contains more than 8 million objects, the VizieR catalog's service which provides access to about 17,000 catalogs (being the most complete library of published astronomical data tables available online), and the interactive sky atlas Aladin which allows one to visualize sky surveys and data from SIMBAD, VizieR and from external archives and databases thanks to IVOA standards and protocols implementation.
The Strasbourg Planetarium was part of the Observatory from 1986 to 2008. It is now managed by the Garden of Sciences. The aim of this department is to facilitate the access of the public to scientific research in all its diversity and to make him apprehend Science in a playful and creative way.
The current planetarium is equipped with an 8m fisheye digital system which will be replaced in 2021 by a state-of-the-art 8K digital system under a 15m dome in a brand new building. This opportunity as well as the historical relationship with the Observatory encourages us to question ourselves about the boundaries between public outreach practices in the planetarium and academic research in astronomy.
Considering the fact that the "modern, networked, digital planetarium is a world-class big data visualization facility"[1], the incoming "data deluge" from the new ground- and space-based observatories, instruments and missions[2], and the new possibilities offered by the Data2Dome initiative[3], we assume that there are at least three issues that we should be able to resolve as planetarium science communicators : give clues to the public about how astronomy research is performed, further engage our public toward citizen science, and bring the scientists inside the planetarium not only to communicate about their work but also to benefit from the visualization particularities offered by the dome in the frame of their research (with a seamless access to their data in both cases).
These issues may be partly resolved with the implementation inside the simulation software commonly used in the planetarium community of the Hierarchical Progressive Survey (HiPS) standard and the associated user interfaces for search and query. The implementation would facilitate the access and visualization of astronomical survey data as shown below with the Aladin Fisheye prototype developed by the CDS.

I. ABOUT PUBLIC OUTREACH AND RESEARCH IN ASTRONOMY

I.1 Explaining how research is performed is part of the public outreach

Multi-wavelength, multi-messenger and time-domain astronomy stand among the subjects that we should be able to illustrate inside the planetarium with the appropriate explanations to a specific public. The methods and the tools used to investigate the data make sense, especially with the current change in scale, also known as "big data".

When the Large Synoptic Survey Telescope sees first light, it will produce the deepest and widest image of the Universe thanks to its 8.4m mirror and 3.2 gigapixel camera. But as fast and wide field the LSST will be, its most transformative aspect concerns how it will change data management practices with an output of 15TB every night during 10 years[4]. The same could be said about the Square Kilometer Array and any other instruments or missions scheduled in the astronomy field (and large already existing surveys like SDSS and Gaia): data and the software to manage and analyze it are as essential as the instruments to astronomy.

This "data deluge" characterized by enormous information streams and databases implies that a direct look at even a fraction of the data will be incrementally difficult, even with the best visualization tools available. Today the most advanced digital full dome planetarium projection's systems are able to display tens of megapixels' images (about 50 megapixels for the best). If we take into account the plausible technological advances for the coming years, (e.g., 8K projection matrices, or even LED panels display domes) we could talk about hundreds of megapixels, which is still far away from the giga- and even terapixels all-sky surveys generated by modern instruments.

This bottleneck between surveys and visualization can be resolved through different means. We believe that a tiling mechanism that decomposes and transforms the data into series of depth levels is one of them, which is what the HiPS standard aims to provide while also allowing multi-wavelength and multi-messenger visualization.

I.2 Citizen science

While not being its main focus, the planetarium's ability to display the same data as used by professional astronomers and researchers through the same standards and software, allows citizen science to be more easily accessed for our willing audience. The planetarium should make the connection between the scientists and the public at the first level and work as one of the entry points to these activities. It also gives us the opportunity and the tools to concretely answer questions concerning how knowledge is produced and with which methods.

An exciting aspect of the HiPS standard is the availability of a Web client (Aladin Lite and its implementations, see below) which can work as a relay at home for the ones eager to further engage themselves into this domain.

As important as the citizen's participation in science is on the outreach side, it may also be on the research side: "Citizen volunteers should be thought of as members of the science collaboration" says Amanda Bauer, Head of LSST Education and Public Outreach[5]. The streamlined access to these data in dedicated environments (like Zooniverse[6]) allows almost anyone to participate in serious research projects.

I.3 Invite the scientists into the dome

Key facts and advantages of the planetarium as a world-class big data visualization facility for the scientists have already been discussed in great detail inside the community. Tom Kwasnitschka, staff scientist at the GEOMAR Helmholtz Centre for Ocean Research Kiel in Germany, explains that "when my colleagues and I are immersed in this visual environment, we can really communicate about our data. We see the same things and point them out to each other. We discuss hypotheses face to face as humans, not as avatars. There are no clunky goggles to isolate us and stifle conversation."[7]. It also seems important to notice that the dome itself is a particular way of visualizing data, which can bring new insights, or as Dr. Mark SubbaRao, Director of the Space Visualization Laboratory at the Adler Planetarium in Chicago, puts it: "I think it is up to all of us in the planetarium community to invite local scientists into our domes to let them experience seeing their data in the planetarium. Only then will they begin to understand the power of the planetarium."[8].

Sometimes the planetarium digital simulation's system itself might be a hurdle or act as a barrier to these facts, using it as a "research tool" or as a specialized communication tool. If we want to invite the scientists into the planetarium in an effective way, the process of going from data to dome should be as streamlined and transparent as possible: they should be able to access and interact with their data into the dome in the same way they do in their laboratories or computers. In order to focus on the data itself, there shouldn't be any step required to transform or translate it for the planetarium: the same open formats already endorsed by the International Virtual Observatory Alliance[9] should be implemented inside the planetarium simulation software we commonly use in our community.

It is also worth mentioning here some facts about difficulties as cited by Josh Peek, Associate Astronomer and DSMO Project Scientist[10]: "Multidimensional visualization is key for understanding and exploring big data, federation of big data systems will be needed if we expect to visualize them with a range of tools".

We think the HiPS scheme is one of the solutions to these challenges, as detailed below.

II. HIERARCHICAL PROGRESSIVE SURVEYS

II.1 Overview of the IVOA recommendation

Hierarchical progressive survey is the hierarchical tiling mechanism which allows one to access, visualize and browse seamlessly image, catalogue and cube data. Clients implementing the recommendation endorsed in 2015 by the IVOA get access to progressive sky surveys with the capability to zoom and pan on any regions, or in other words, to browse big data.
The HiPS scheme uses the HEALPix[11] framework for mapping a sphere and transforms it into tiles and pixels which contain the astronomical data. HiPS emphasizes usability and tries to abstract the scientific details while preserving it.
A HiPS server is a regular HTTP site which provides HiPS surveys and can be seen as a simple hierarchy of directories and files, making it very straightforward to deploy.

Figure 1 – "The more you zoom in on a particular area, the more details show up"

There are currently about 400 HiPS surveys available for 200TB of pixels provided by several collaborative servers and these statistics are continually growing. HiPS are generally generated by the data providers and distributed by several sites for efficiency reasons. For more details about the HiPS scheme, including usage and principle (HEALPix tessellation technique, HiPS tiles), encoding method, distribution and registration protocol, but also client access and use procedures, we refer to the research article "Hierarchical progressive surveys"[12] and the IVOA recommendation[13].

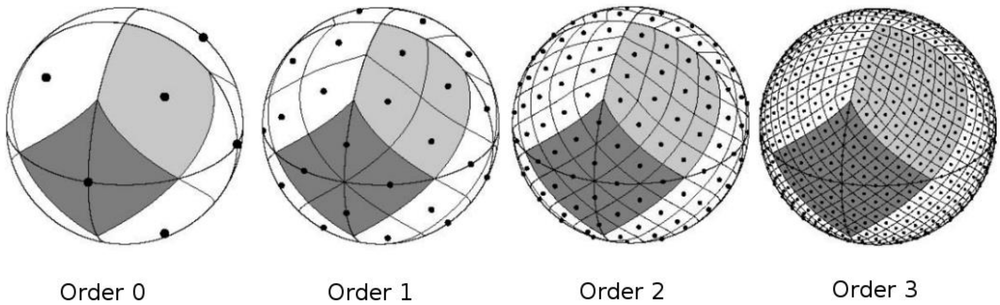

Figure 2 – The HEALPix partitioning of the sphere

II.2 The Aladin Fisheye prototype

In order to test the HiPS usage inside the planetarium and get a first idea about implementation particularities for the dome, the CDS prototyped a version of Aladin destined to our current mono-projection fisheye digital system. This prototype is made of a "cinema mode" Aladin (zenithal equidistant projection without user interface) and a controller plugin. It consists of a user interface dedicated for the planetarium on a control monitor, with chosen functionalities like creating and executing scenarios, selecting and loading surveys, zoom level etc.

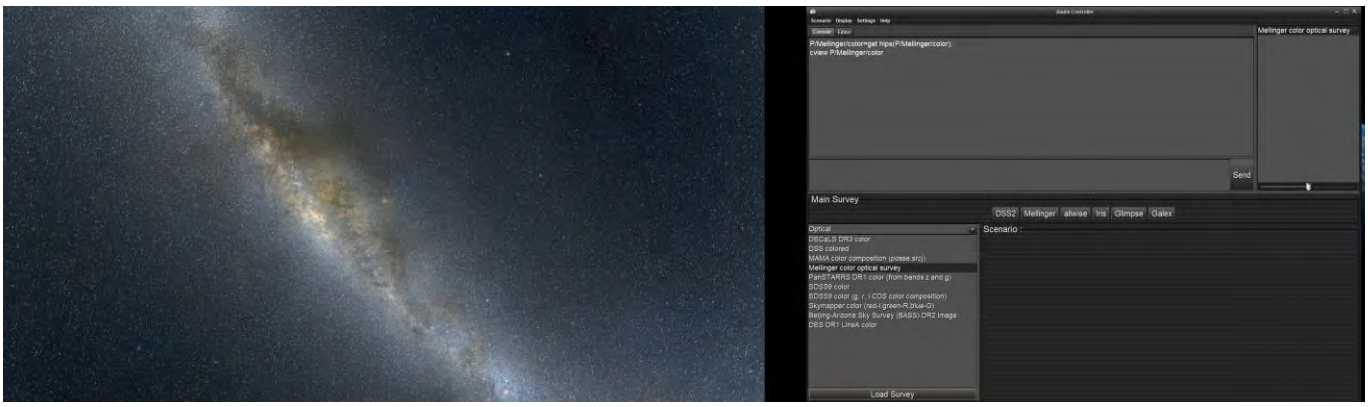

Figure 3 – Aladin Fisheye (truncated) showing the Mellinger HiPS survey through Aladin Controller

There are two main ways to interact with Aladin Controller as we usually do with planetarium simulators: a real-time usage and a pre-recorded one through scripts (or scenarios here) that will launch commands entered inside an editor console.
In this prototype we mostly promote the multi-wavelength aspect of HiPS surveys with the possibility to load a survey either by name or by wavelength (Radio, IR, Optical, X and Gamma) and display it. The editor is a way to automate a more complex

use of Aladin Controller, for example by pointing an object in an optical survey, zooming on it, show the same object in another wavelength by changing the survey, and zoom out.

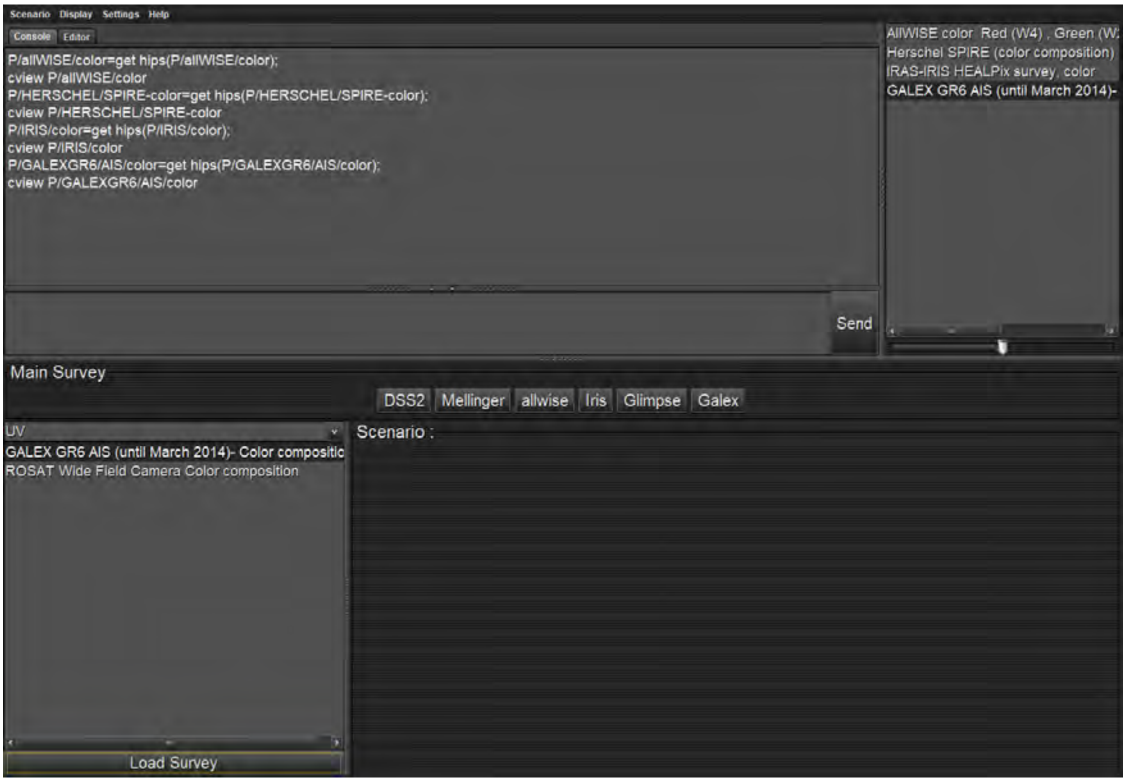

Figure 4 – Aladin Controller's functionalities

The evaluation of the prototype was made on two levels: the relevance of the functionalities and the UI's usability in regard to its use in a scientific mediation frame, and the technical display's aspects (fluidity, distortion etc.). As expected on the functionality and usability side, the multi-wavelength and the depth of the HiPS surveys offer great opportunities for scientific mediation and cover a broad list of subjects to illustrate. This is mostly due to the possibility of directly querying the CDS and immediately visualizing the corresponding data.
The technical side's results are encouraging even if a completely fluid and undistorted real-time fulldome image is very challenging to obtain on our 8m dome. This should be even truer on larger domes.
Considering that Aladin - as a HiPS client - is not originally made for a dome usage, the implementation of the HiPS scheme in modern planetarium simulators should resolve this problem.
This study was only a proof of concept and the aim was not to provide a new visualization tool for planetariums. Since this experiment, Stellarium has integrated the capability to handle HiPS surveys.

II.3 Adoption of the HiPS standard in the visualization landscape

Aladin Desktop[14] is the original HiPS client developed at the CDS and widely used. Aladin Lite[15] is the lightweight version of the Aladin tool that runs in the browser and is easily embeddable on any Web page.
Other implementations of Aladin Lite exist: ESASky (ESAC)[16], JUDO2 (JAXA)[17], SkyMap Viewer (LIGO-VIRGO)[18].
Among the other HiPS clients available we can also cite: MIZAR (CNES)[19], STScI portal (NASA)[20], openWWT (Microsoft)[21], SkyView (NASA)[22], proto (China)[23], and the famous open source planetarium software Stellarium[24].
The Data Management team of the LSST is also adopting HiPS as a standard data product among others[25].

CONCLUSION

Based on our observations we can say that HiPS may be a practical solution to solve some of the challenges we face to promote a modern and "data-savvy" planetarium, whose purpose goes beyond its traditional role of education in astronomy. Explaining how research is performed is part of the public outreach, because this kind of approach can change how the people perceive and understand Science. This can affect their vision of the world, as well as encourage them to engage in citizen science programs. The streamlined and transparent process of going from data to dome allowed by HiPS is a way to invite scientists into our planetariums to share their research with the public, but also to benefit from the unique visualization capabilities offered by the dome in the frame of their work.
As an open astronomy standard endorsed by the IVOA, whose available data and adoption are continuously rising, we showed how HiPS could be implemented into our planetarium software simulators in order to allow us to build bridges between Science and society.

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[19] https://sitools2.github.io/MIZAR/
[20] http://www.stsci.edu/
[21] http://worldwidetelescope.org/webclient/
[22] https://skyview.gsfc.nasa.gov
[23] http://www.china-vo.org/
[24] http://stellarium.org/
[25] https://jira.lsstcorp.org/browse/RFC-441?jql=labels%3D%22HiPS%22%20

Making astronomical topics clearer into the dome

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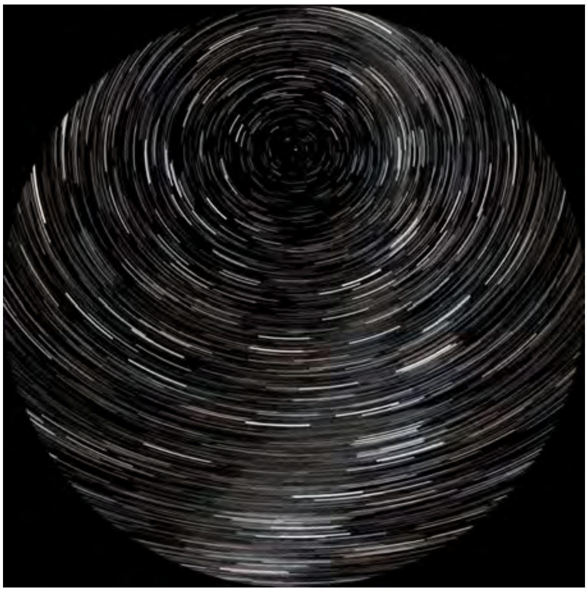
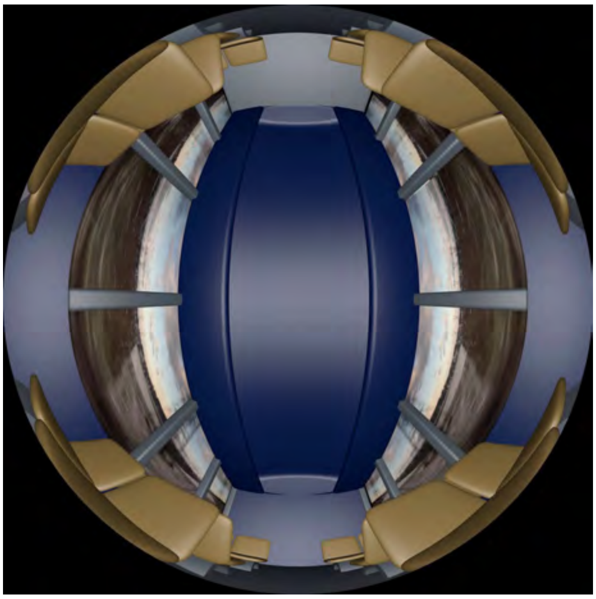
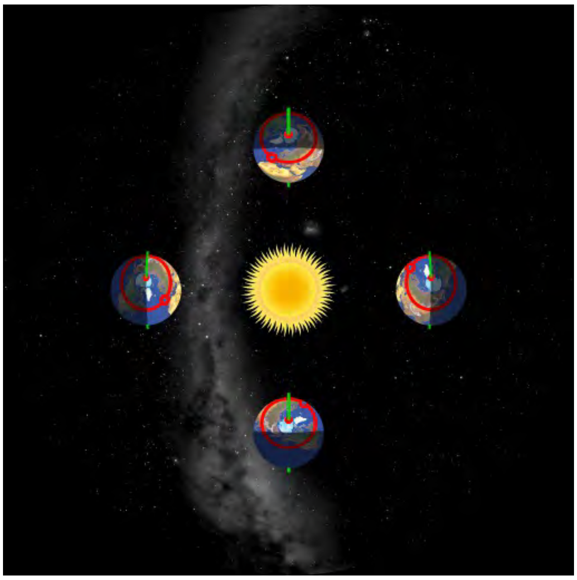
ABSTRACT:
With more than 20 years in the planetariums field, I tried to develop as many fulldome graphical explanations about astronomical topics as possible. More than 400 NightshadeLegacy/Stellarium360/SpaceCrafter scripts and fulldome videos answers have been developped for this purpose. Here is a pot pourri of my results for the most frequents questions rised by the audience with screen captures in fisheye format. You can reproduce it yourself with your planetarium or ask me for some in exchange of what you've done that could be traded...



Startrails are permitting to locate easily the celestial north pole and ask why it stays immobile.

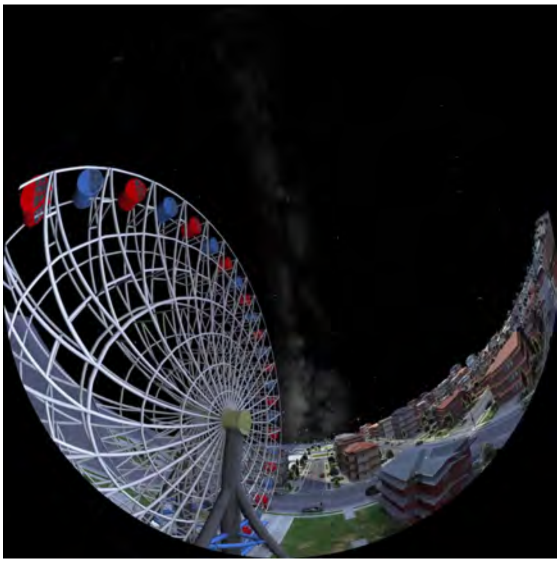


Being immersed inside a train permit to talk about relative motion as well as the way we don't feel speed We have to care if the train increase or decrease speed.

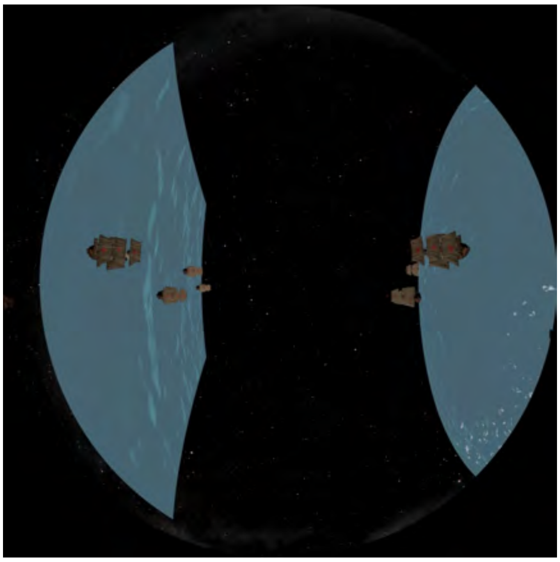


Seasons viewed from above to talk about the pole being always at night or day and the length of the day.

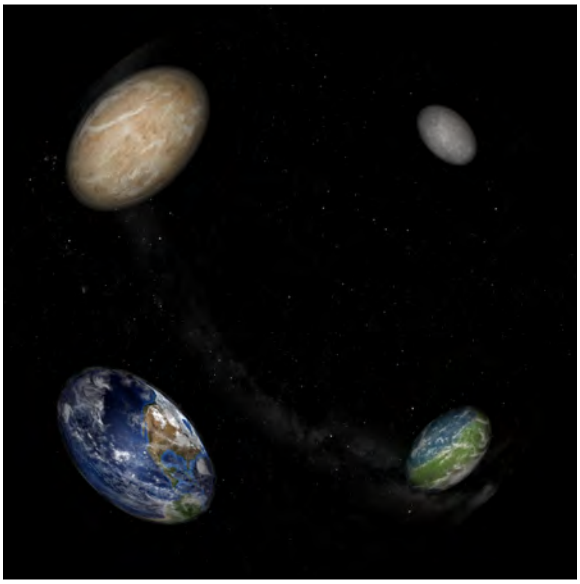
Riding to explain Earth rotation for children.
That way we can deal with the still summit of the riding as well as relative motion. We do see trees and houses passing by.



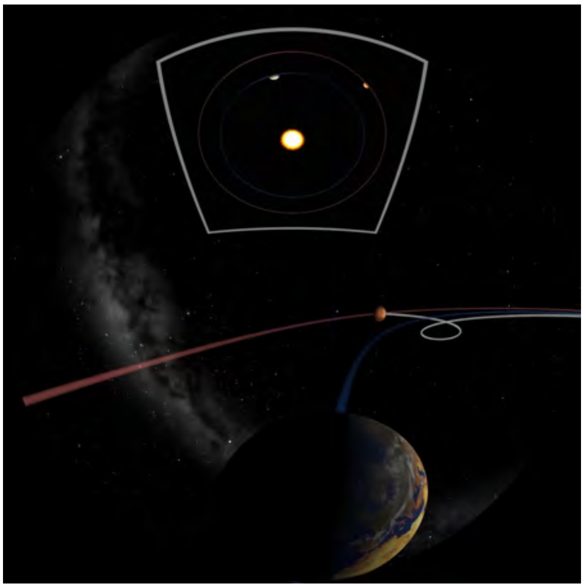
Passing through a ferris wheel permits to compare its shape with the milkyway as seen from inside.



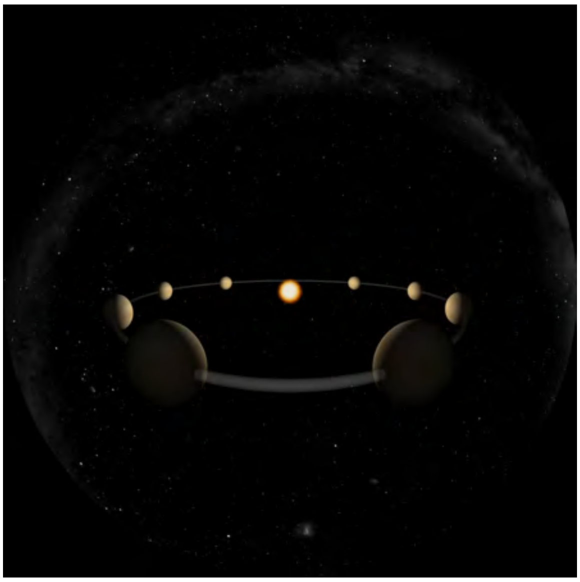
Compare the view of boats at the horizon with a flat sea compared to a spherical one.



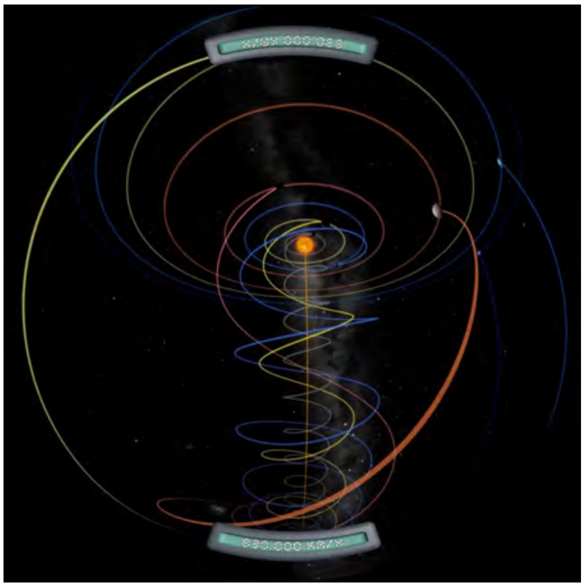
Compare the evolution of the telluric planets side by side.



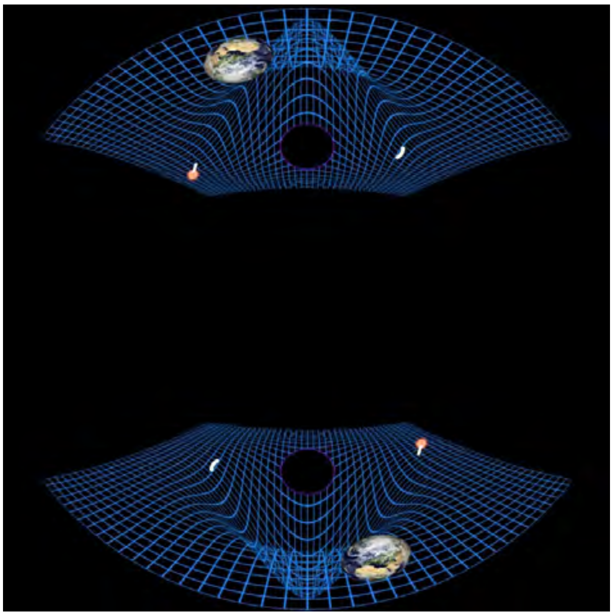
See retro motion of Mars with two points of view.



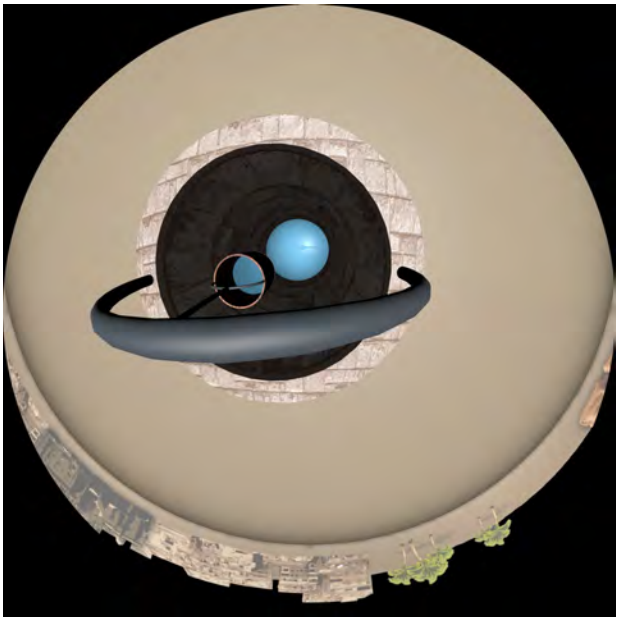
Venus phases viewed by Galileo permitting to consider that all the planets are orbiting the Sun.



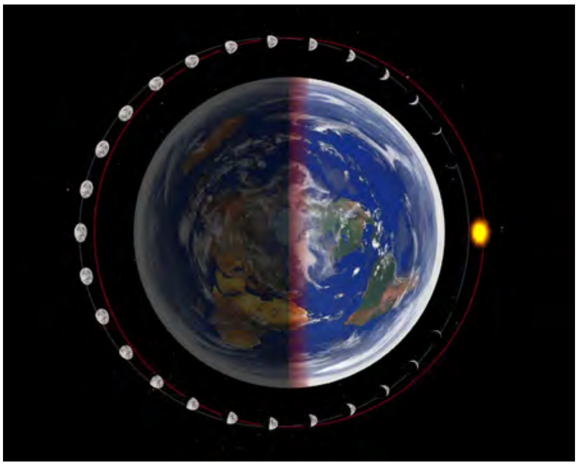
Motion of the planets associated to the movement of the Sun to view the helicoidal motion in fulldome.

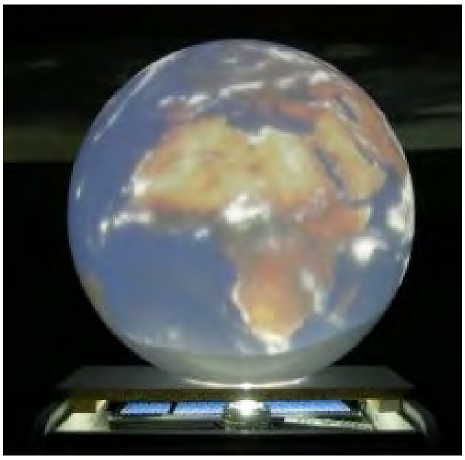


Visualize the double image of a star caused by a black hole.

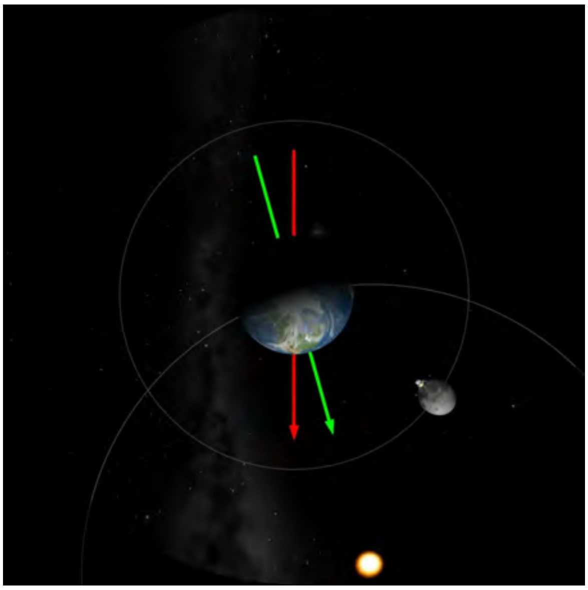


Talk about Eratosthenes consideration of the Sun reflection in a well in Syena in an immersive way.

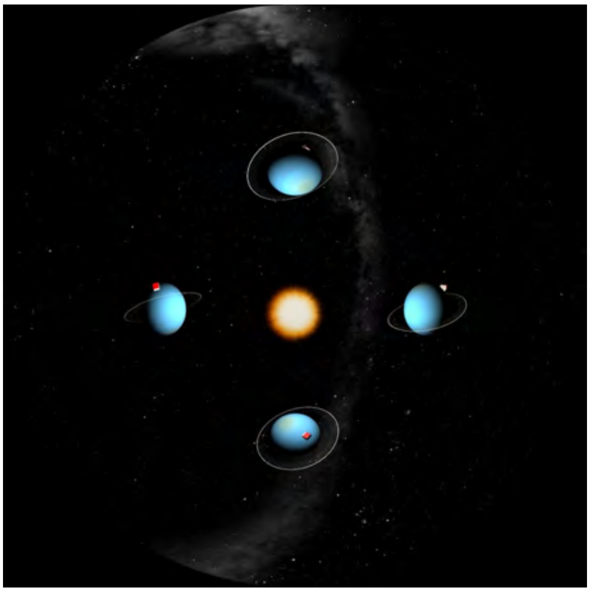




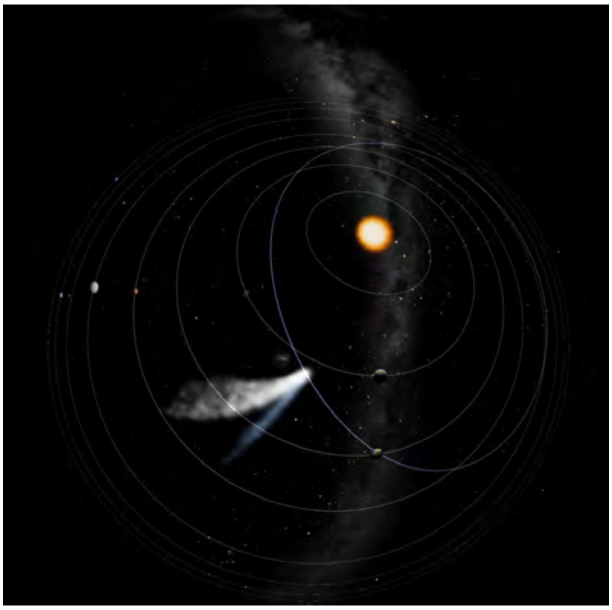
Talk about the moon phasis with a fisheye planetarium, putting a globe on top of the fisheye but permitting that a part of the image is still being projected onto the dome to see the phasis. That way if you turn around the dome you'll see the Earth globe with phasis an you can associate it with the shape of the Moon seen further away.



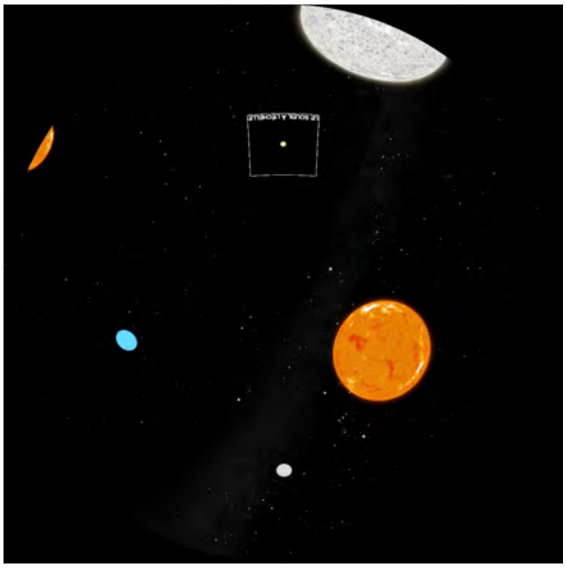
With this scheme, we talk about the difference between synodic period and phasis period.



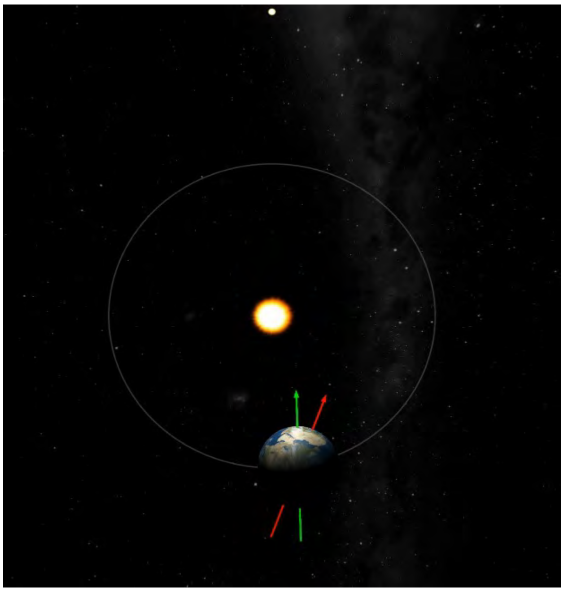
With this little animation you can talk about the strange seasons on Uranus (21 years of night/day).



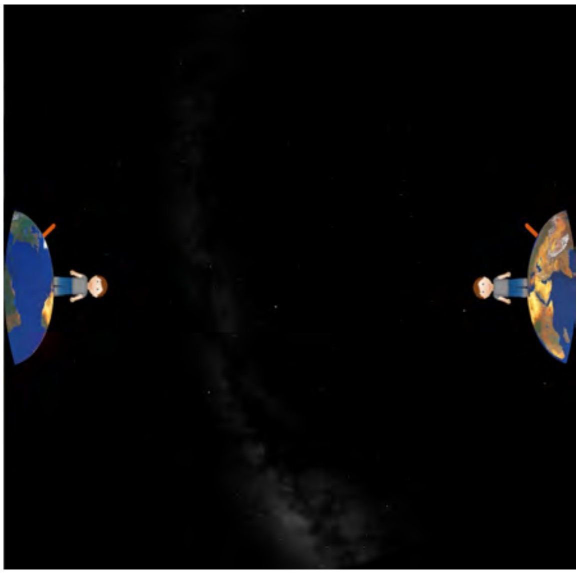
This comet animation permit to talk about the tails and why we get shooting stars each year.



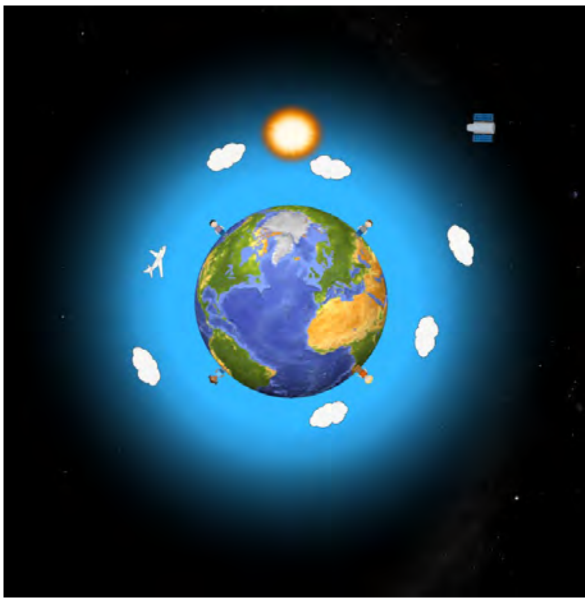
Putting some stars at exactly the Sun distance permit to compare the size and color of the stars.



Compare the day duration with the sidereal period.

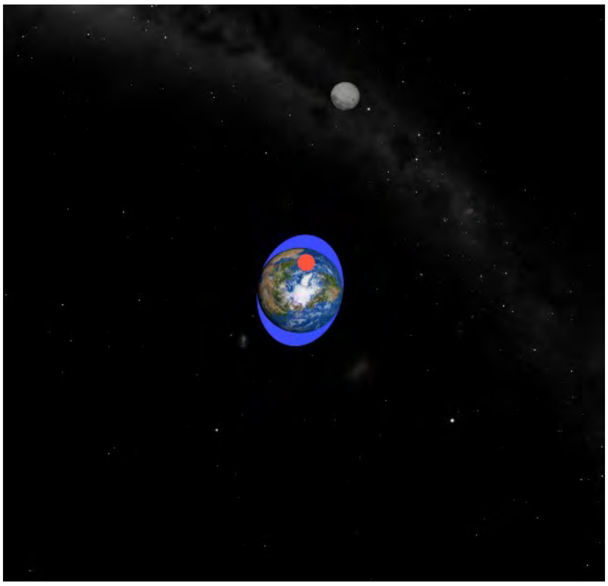


Change of latitude and see what it does to the sky.

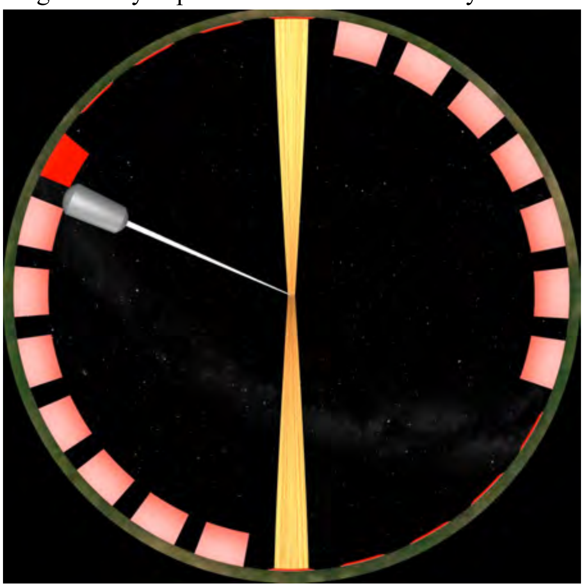


Gravity works where ever we are on the Earth surface.

See the Sun/Moon following us like do the mountains.

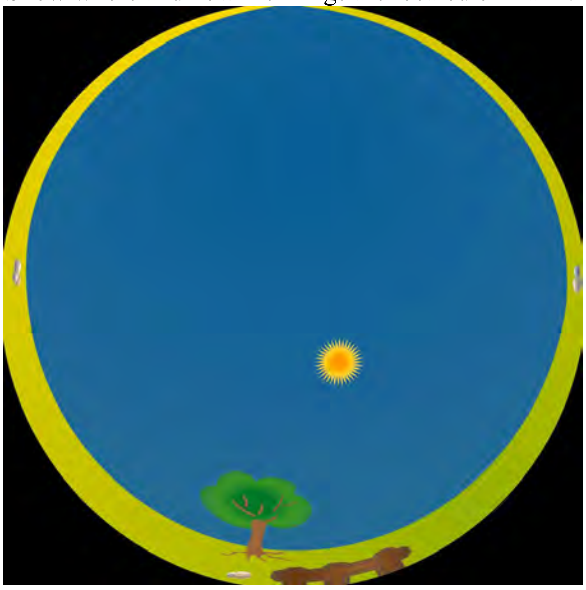


Progressively explain moon tides element by element.

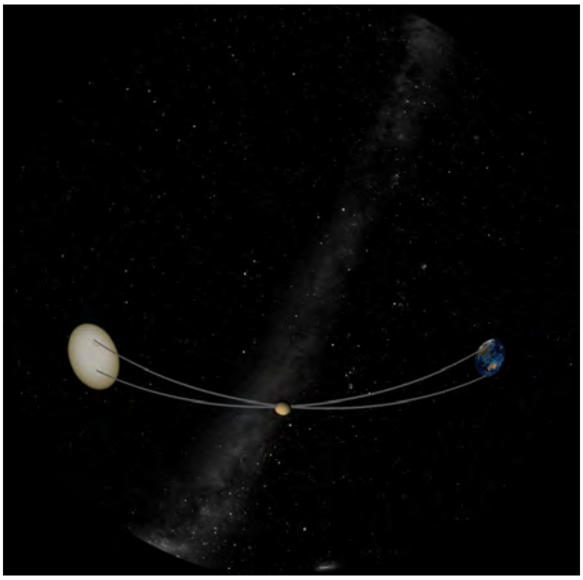


The Foucault pendulum seen from underneath.

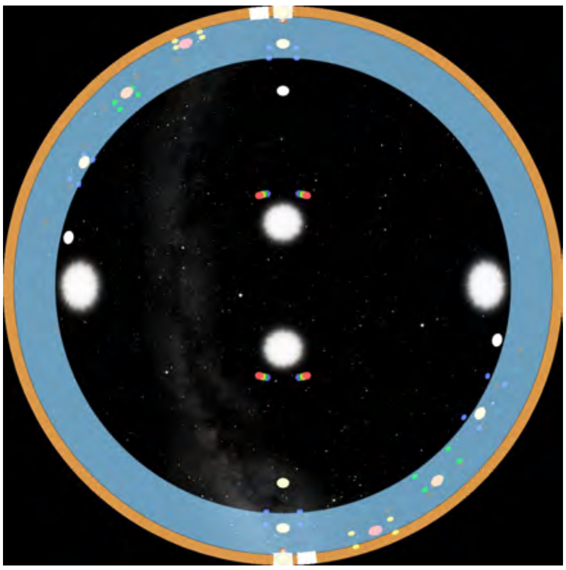
Show where and how the things are located on Earth.



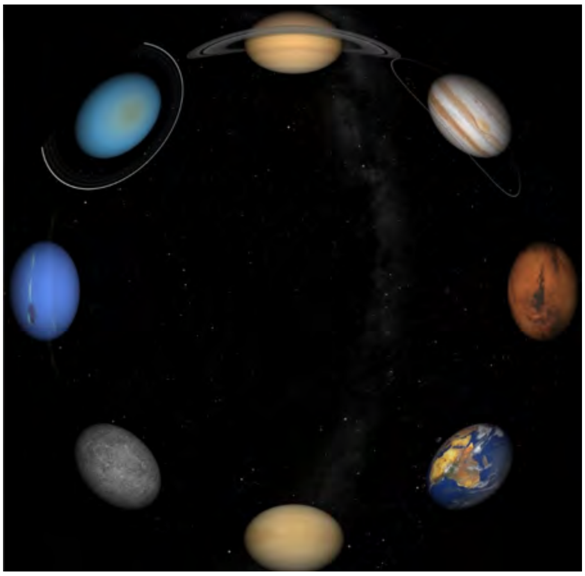
Compare the course of the Sun through seasons
You can locate where it rises/set and its height.

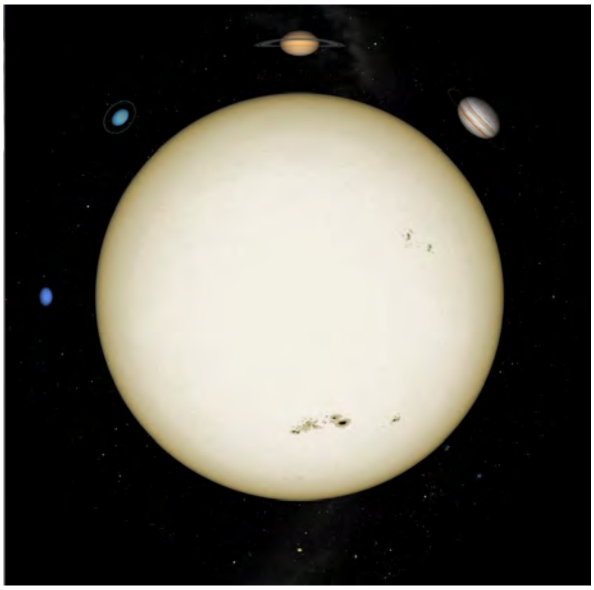


Variation of Venus position influences the angle.

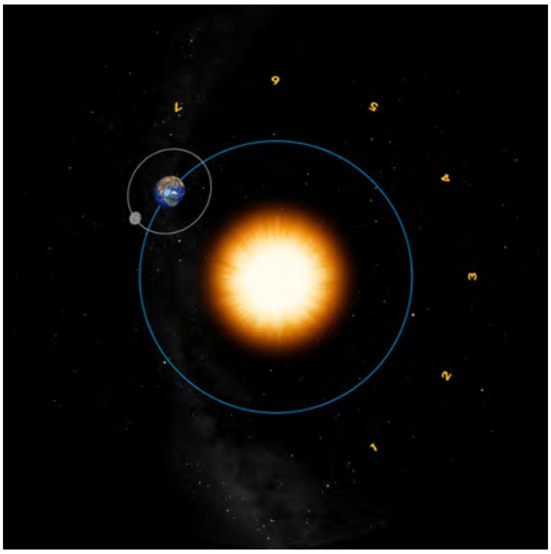


Rayleigh scattering depending on the quantity of atmosphere the light go through.

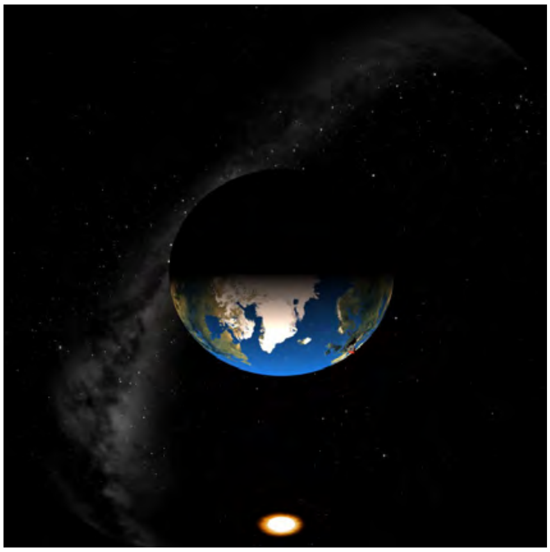




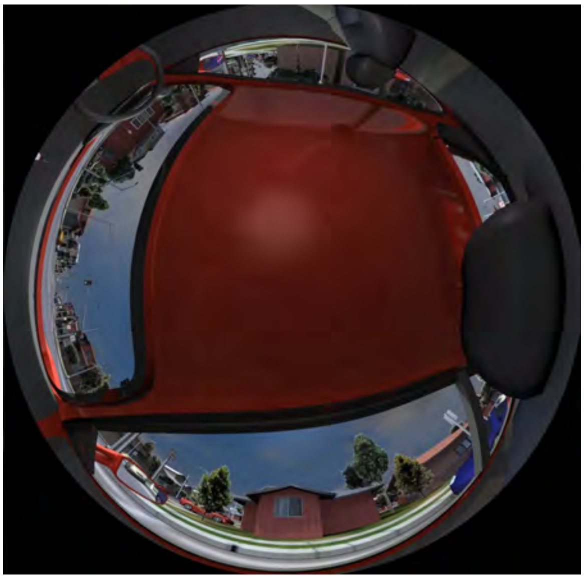
Compare the eight planets with rotation and after that their size compared to the Sun.



Summarize visually between day/month/year duration.



Put a house on Earth and tell what we are doing at each moments of the day/night making the Earth rotate.



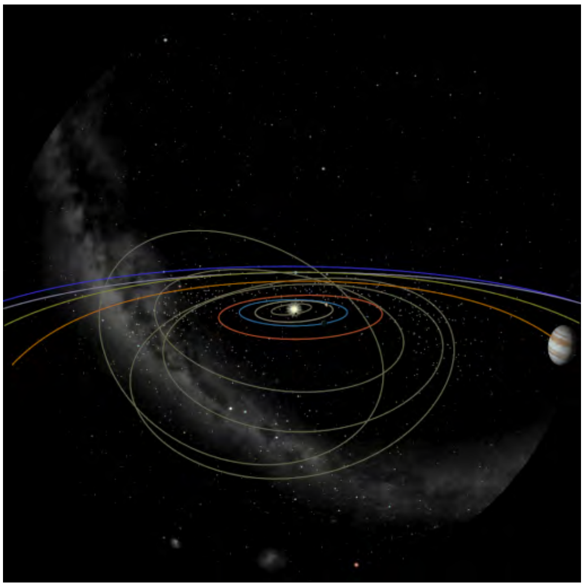
Visualize that in a car we see trees and houses coming from East to West but in reality it's not moving at all.

A blue car (representing the Earth) is overtaking a red car (representing Mars) to explain retrograde motion.

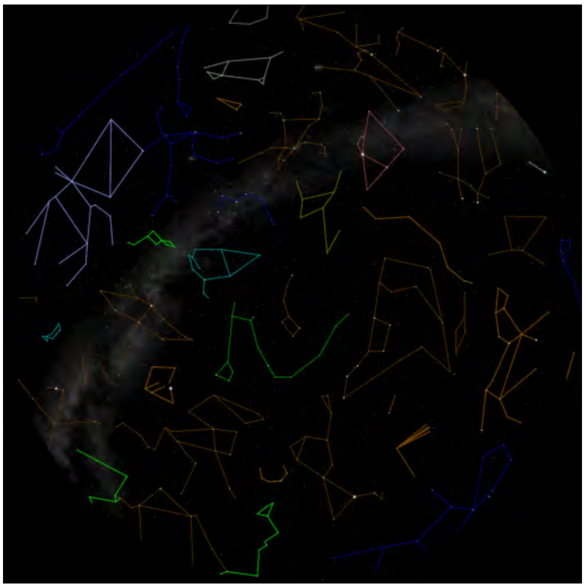
SpaceCrafter : a free planetarium software using the latest graphical technologies

Lionel RUIZ, LSS Open Project
Email: lionel.ruiz@live.fr & Website: http://www.lss-planetariums.info/spacecrafter/

ABSTRACT:
In the planetarium field, there are a lot of free planetarium softwares But some appears to be outdated, some are requiring a connection, some are filled with bugs, some are limited in their possibilities, some are too complex to handle or not perfectly suited for a planetarium use. Spacecrafter is a free open source software based on Stellarium but redesigned with the latest technologies of multi-threading and openGL to fullfil the desires of the planetarists With the ability to manoeuver through space and time, you can view and explain everything related to astronomy in an immersive way. Demonstration of the possibilities of the software: use of a Joypad, play VR360 video contents, elongations and trajectories trace, interactive selection of constellations, meteor showers localized, voyage through the solar system, the Oort cloud and stars, 3D objects integration enhanced, scripting possibilities, video with keycolor playback, planetary flyby, atmosphere rendition, precise ephemerids calculation, etc...



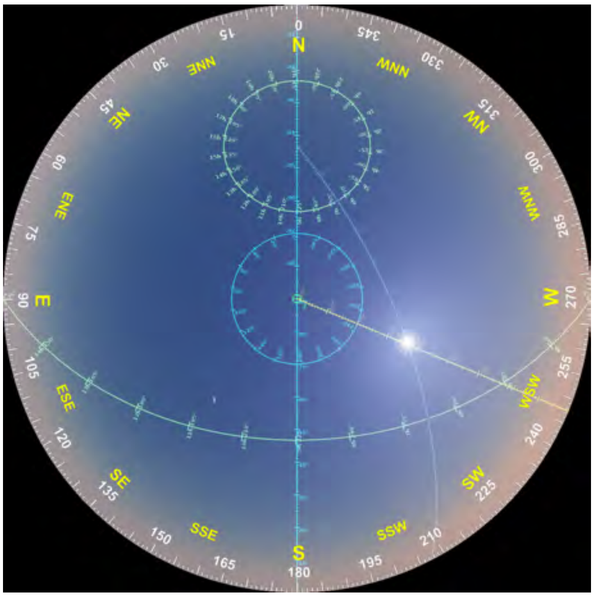
Solar system with all types of asteroids.



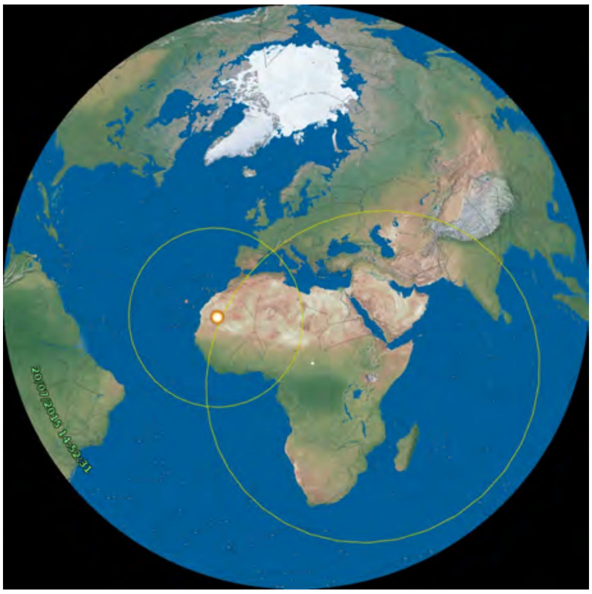
Asterisms in different imaginary visions an colors.

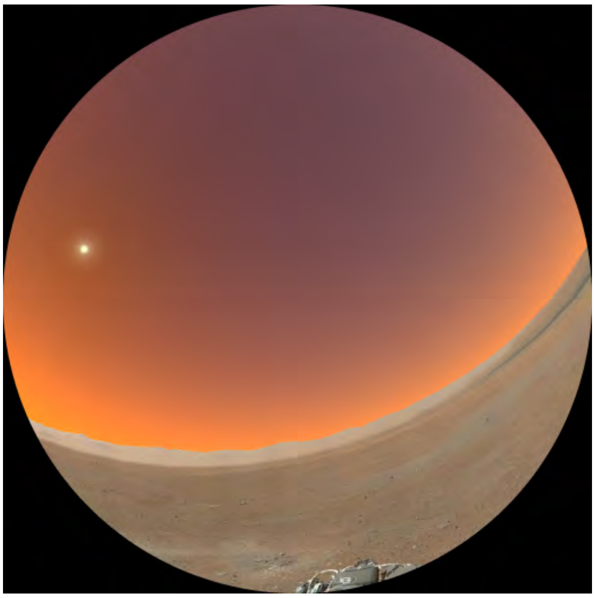
Possibility to draw Mercury elongations and others...

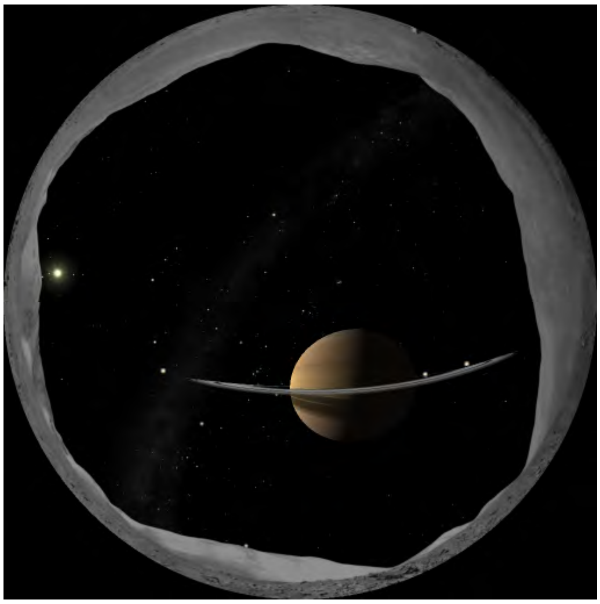
Comet trajectory in front of the stars.



Daylight measurements.


Celestial fix.


Mars from Curiosity and other places.

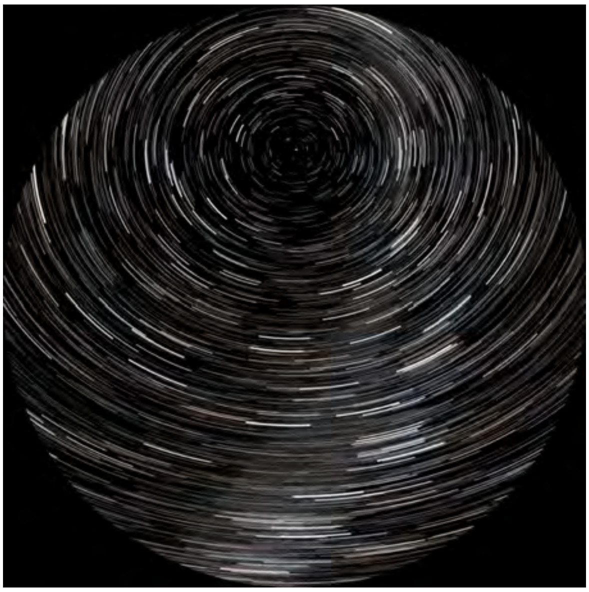

Sautrn view from Mimas surface.


Immersive Adventure special sky culture.

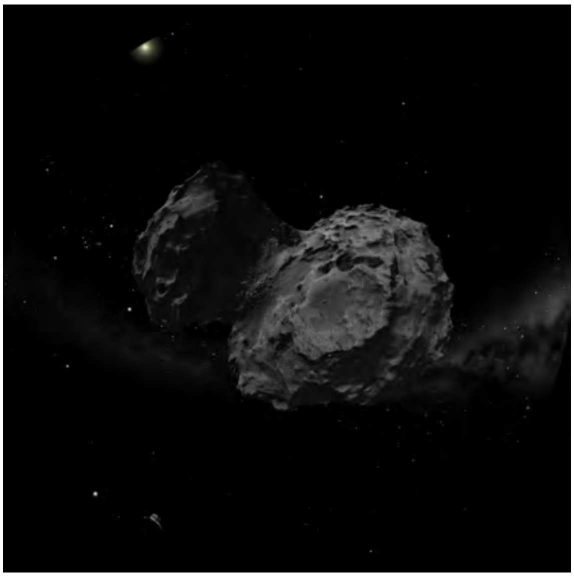

Planetario del Righi culture (Salvatore Fontana design).

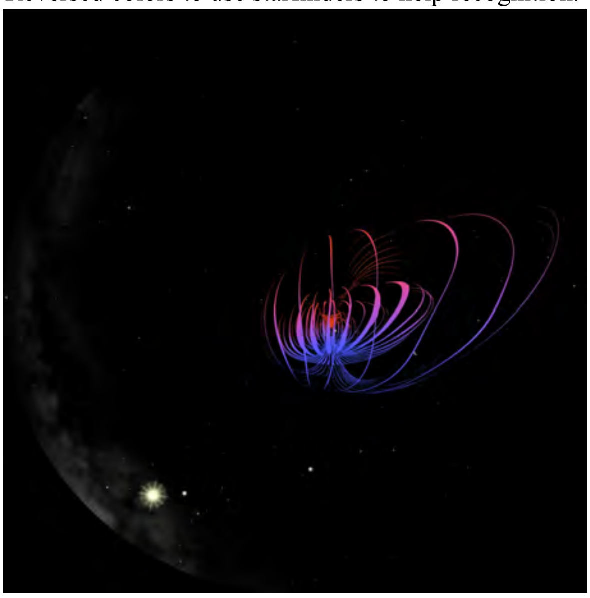

Hevelius Coloured sky culture.

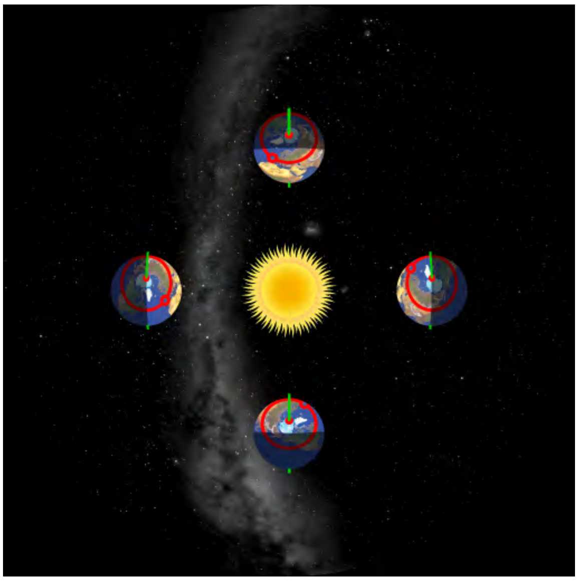

Al Sufi completed sky culture.


Startrails.


Reversed colors to use starfinders to help recognition.

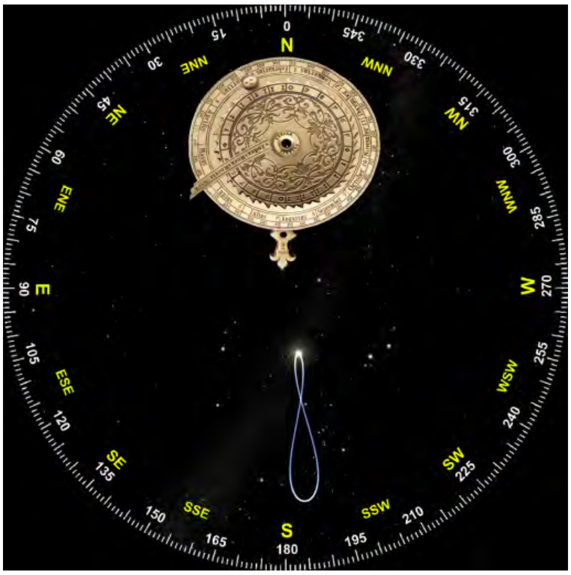

Rosetta mission situation.


Earth magnetosphere rendition.

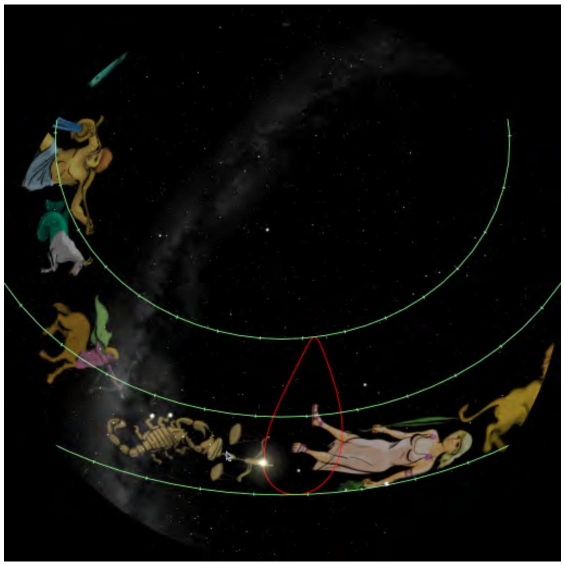


Seasons viewedfrom above using a script.

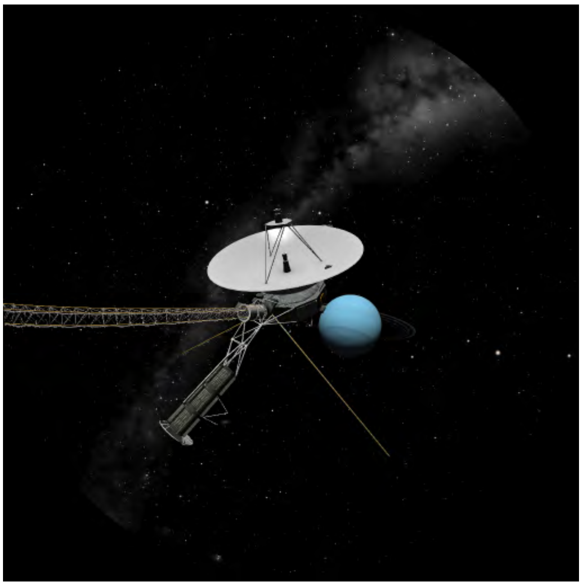
Riding to explain Earth rotation for children.



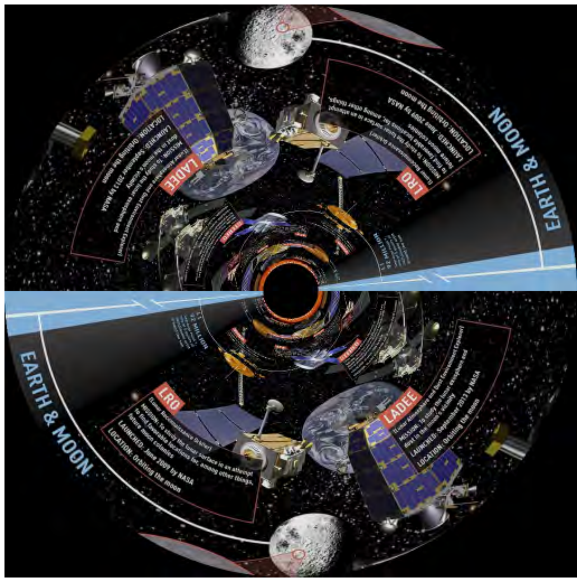
Analemma and Nocutlabe drawing and usage.



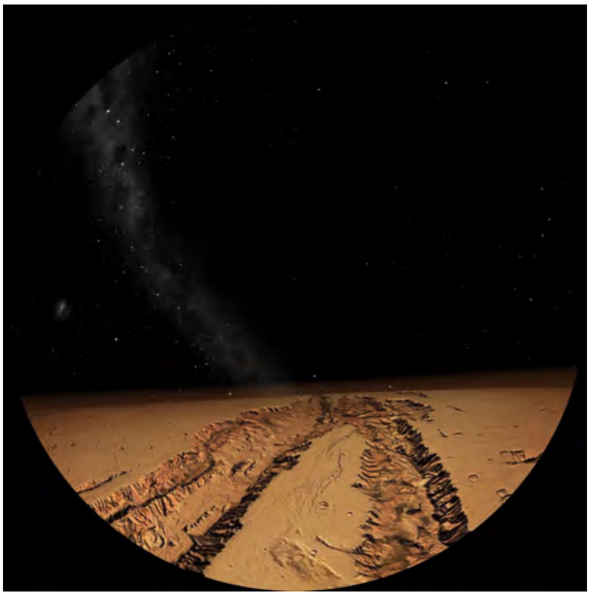
Analemma on Mars.



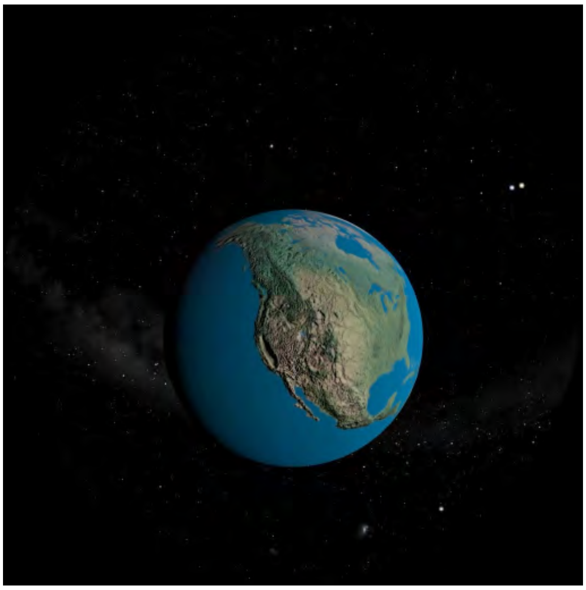
Complex objects integration (Voyager II over Uranus).



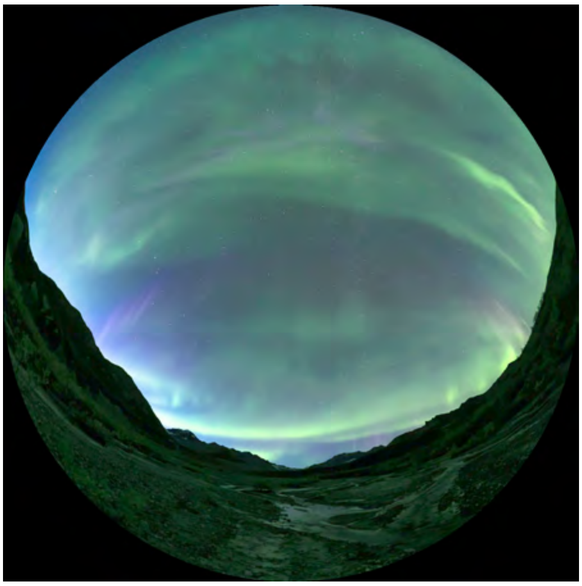
Fly into mapped tube to talk about space missions...



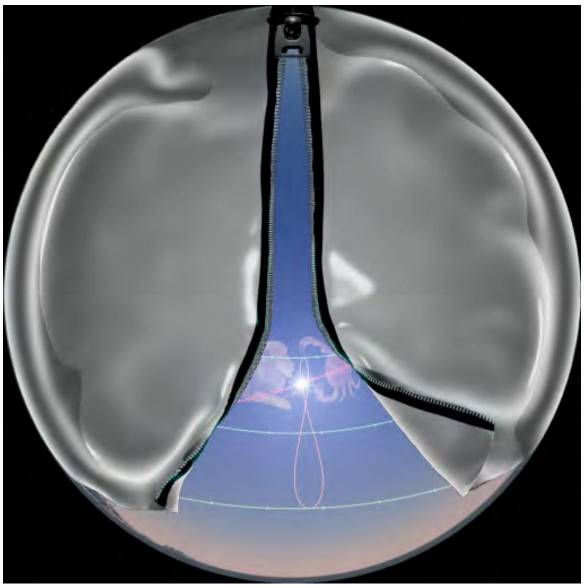
Mars flyby.

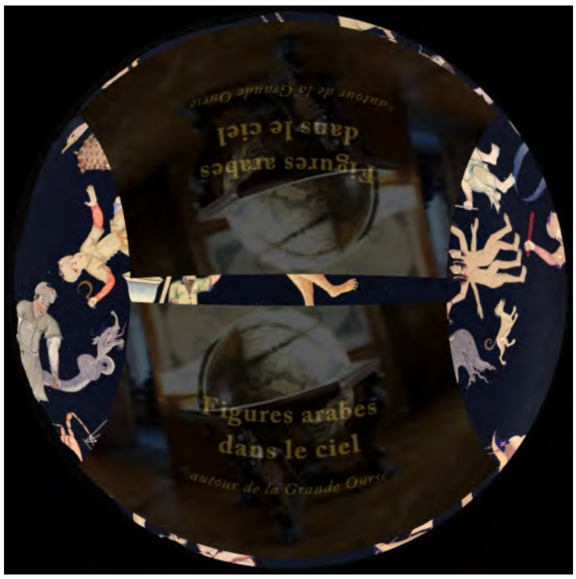


Earth altimetry and maps availables and switchable.

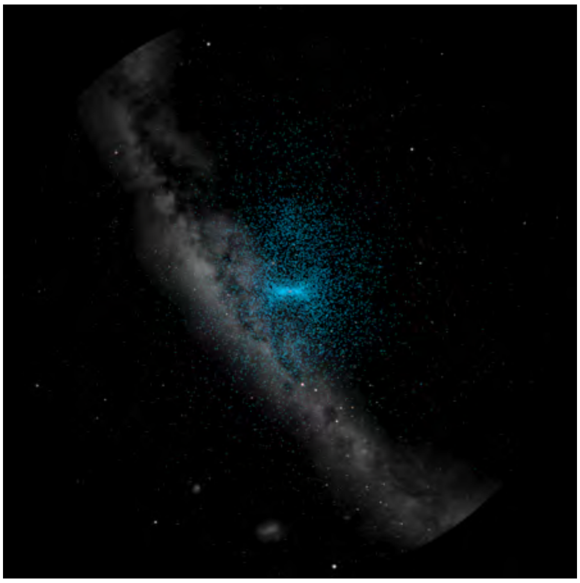


VR360 contents player for dome with joypad use for interactive navigation (possibility to zoom or compress on the fly).

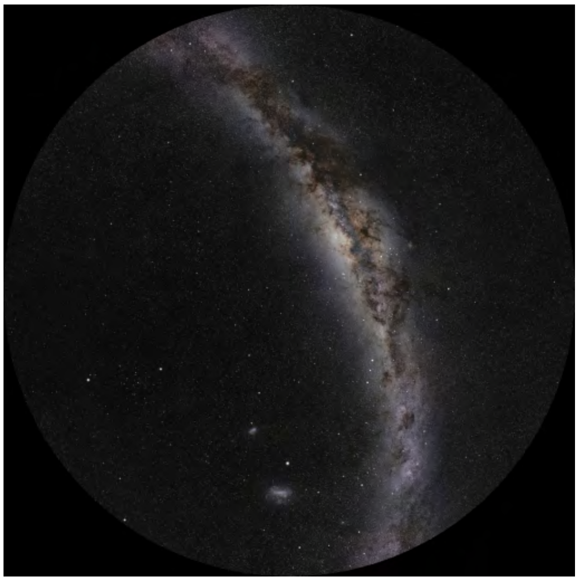




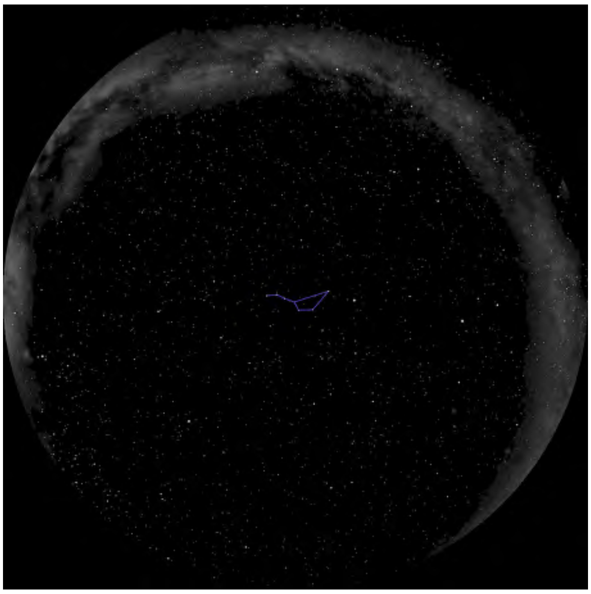
Play fulldome videos with integrated transparency showing the software in background or duplicated rectangular videos



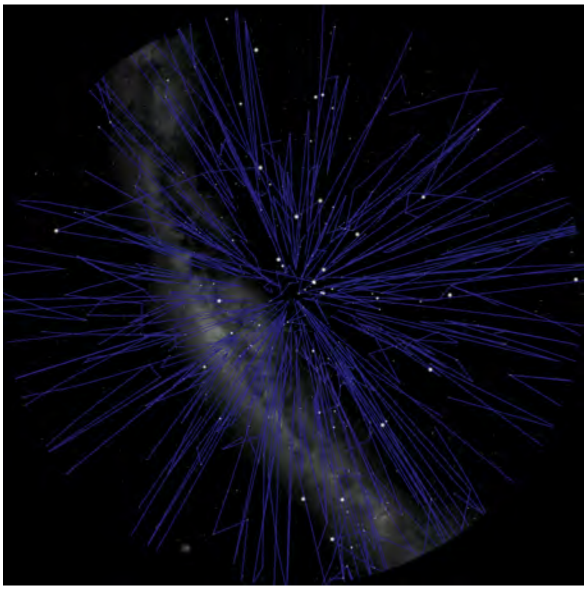
Oort cloud model integration.



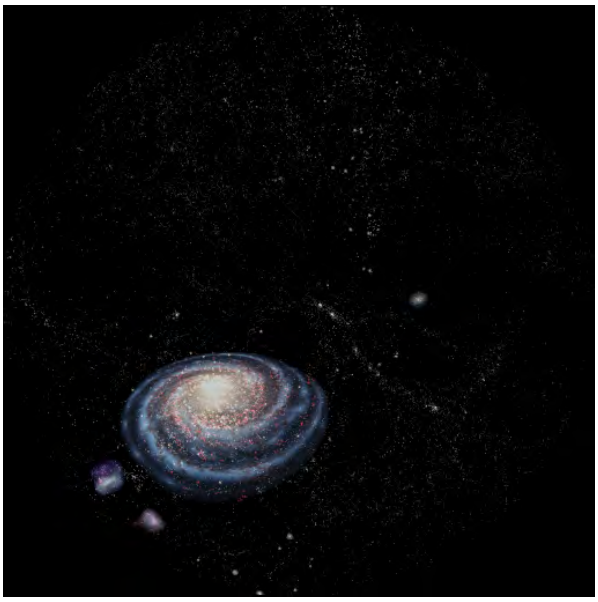
Go through 3D deepsky objects in the milkyway.



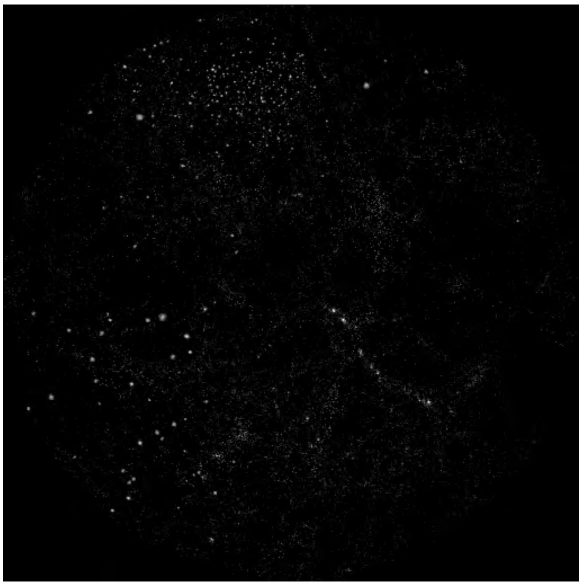
Fly around the big dipper.



View the asterisms from elsewhere in the milkyway.



Fly around the Galaxy...



Or visit the galaxies clusters structures.

To download or view other possibilities, go to http://www.lss-planetariums.info/spacecrafter/

Planetarium Dome as a Cultural Centerpiece:
Innovative Approaches and Collaborations at a Planetarium in Japan

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Keiichi Setoguchi*(setoguchi@expocenter.or.jp)
Minoru Kubo*(kubo@expocenter.or.jp)
Brian Landberg*(cielowatcher@gmail.com)

* TSUKUBA EXPO '85 MEMORIAL FOUNDATION

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Keiichi Setoguchi: Director of Operations, TSUKUBA EXPO '85 MEMORIAL FOUNDATION
Minoru Kubo: Senior Executive Director, TSUKUBA EXPO '85 MEMORIAL FOUNDATION
Brian Landberg: Volunteer Instructor, TSUKUBA EXPO '85 MEMORIAL FOUNDATION

ABSTRACT

Tsukuba Expo Center of TSUKUBA EXPO '85 MEMORIAL FOUNDATION is engaged in innovative activities, centered on its planetarium dome. In order to maintain popularity and relevance in a city that is highly educated and increasingly diverse in both nationalities and age-groups, planetarium programs have been developed in collaboration with English-native volunteers from an international school and also experts from local universities. Additionally, evening music concerts have been organized to showcase local musical talents and simultaneously to provide a dual experience of music and science. These collaborations and events are helping to expand community involvement and also to attract a broader audience demography including International/English-speaking visitors.

INTRODUCTION

Tsukuba Expo Center, a hands-on, science museum located approximately 1 hour north of Tokyo by train, has a world-class (25.6m) diameter planetarium dome. The city of Tsukuba has a unique demography in Japan, home to a highly educated and international population, since it is the location of 32 national research facilities (including JAXA, the Japanese space agency, where multiple astronauts have worked) and multiple universities Tsukuba Expo Center is operated by TSUKUBA EXPO '85 MEMORIAL FOUNDATION, was originally established at the former site of the 1985 Technology World's Fair (Tsukuba Expo '85), which attracted more than 20 million visitors from around the world in that year. The Center strives to continue the legacy of that event by cultivating the spirit of wonder and curiosity through science and technology for people of all ages, nationalities, and backgrounds. In 2017, Expo Center attracted a total of 191, 817 visitors, more than 60% of whom enjoyed planetarium programs. {Fig. 1}

Fig. 1 – External View of Tsukuba Expo Center (planetarium dome visible on left side)

The planetarium of Tsukuba Expo Center employs a hybrid, digital and optical projection system, featuring a Konica-Minolta Geministar-III optical planetarium to project up to 350,000 stars in the vicinity of the Milky Way galaxy and 12,900 other celestial objects, down to about 7.6 magnitude of brightness. The systems also employs a Konica-Minolta SKYMAX DSII-R2 (4K) digital system employing 6 harmonized Barco projects and the Digital Sky (DS) simulation software. The DS system includes a 3D universe simulator based on data from NASA and the New York Museum of Natural History. {Fig. 2, Fig. 3.}

Fig. 2 – Tsukuba Expo Center planetarium (interior)

Fig. 3 – Tsukuba Expo Center planetarium (digital projection system)

I. PLANETARIUM PROGRAMMING

I.1 Original Program Productions

Uniquely in Japan, Expo Center produces its own original planetarium programs (pre-recorded/pre-programmed, hybrid programs) at a seasonal cadence. These programs may also be licensed for use at other planetariums, and some have enjoyed significant popularity at several other sites within Japan. Since 2006, a total of 47 programs have been produced, typically focusing on topics of: 1) unraveling the mysteries of the universe; 2) Learning about the planets and constellations; 3) Significance of stars and constellations from cultural or historical viewpoints

I.2 Options for a More Diverse Audience

Since 2014, in order to better serve the diverse community, we are offering an additional English language audio option, aimed at a non-Japanese speaking audience (or anyone interested in improving English listening skills). Moreover, Japanese subtitles and audio support for hearing impaired or elderly audience members have also been made available. The development and launch of these optional features benefited from inputs and consultation from experts at local companies, research organizations, and universities, including faculty from *Tsukuba Gijutsu Daigaku*, Japan's only national university for education of students with hearing, visual, or other disabilities, who enabled optimization of the user experience for all viewers simultaneously.

To date, 12 programs have been produced with accompanying English audio, and to our knowledge this is a pioneering project, i.e. Expo Center is Japan's only planetarium that continuously self-produces its own original feature programs and also provides options for English speakers and hearing-impaired visitors. Moreover, for recording the English language audio, we have invited the voluntary participation of popular and influential members of the English-speaking community in Tsukuba, including students and faculty from Tsukuba International School (TIS), an accredited International Baccalaureate School. {Fig. 4}

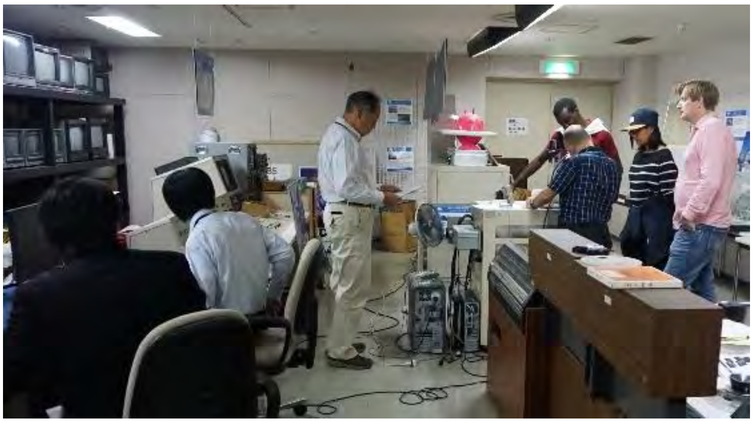

Fig. 4 – Recording scene of English language audio track

I.3 Recent Programs and Collaboration Example

In 2017, we have produced programs titled "Enchanting Planets" (a tour of the solar system, including latest scientific updates and images from various space probes); "Giant Meteor Impact into Earth" (a survey of asteroid/meteorite impacts and the prospects for protection from the risks of future impacts); "Star Tales of Old Japan" (explaining the practical value in old Japanese society of using stars for guiding the lives of the people including farmers & fishermen) ; and "Calling Jupiter" (on the mysteries of Jupiter from Galileo's discovery of its moons to the latest data and images from the Juno space probe).

As a specific example of collaborations, the production of the program "Giant Meteor Impact into Earth", which featured several historic meteor events including the Yucatan peninsula (Chicxulub crater) impact of 66 million years ago and the Tunguska impact in Siberia about 100 years ago, benefited from many local experts and volunteers. Researchers and engineers from universities and corporations were consulted about the facts of these and other impacts including one that released fragments over Tsukuba City in 1996. As English voice actors, two volunteers were recruited from Tsukuba International School, which is an International Baccalaureate accredited school located in the city. Furthermore, an interactive exhibit was set up along the exit hall of the planetarium so that audience members could enjoy reviewing the learnings from the program and even provide their own ideas or opinions about how best to react to a future impact threat. The exhibit materials were prepared with bilingual explanations, also with help from Tsukuba International School students. {Fig. 5}

Fig. 5 – 2017 Summer Planetarium Program ("Giant Meteor Impact")

As for the current 2018 summer season, our original shows include our latest animated program, Einstein's Homework" which explains the concepts and technologies of gravitational wave detection, also produced with volunteer voice actors from Tsukuba International School, and a digital program about the Van Gogh's depiction of the stars in his art works, from both artistic and scientific viewpoints.

Fig. 6 – 2018 Summer Planetarium Program ("Einstein's Homework")

Fig. 7 – 2018 Special Planetarium Program ("Vincent Van Gogh's Universe")

II. INNOVATIVE COLLABORATIONS

II.1 MOU with an International School

Starting in October 2017, Tsukuba Expo Center is expanding the collaboration with Tsukuba International School. We signed a formal MOU and announced the joint initiative to local media outlets. Under the MOU, selected 11th year high school student volunteers from can participate from the early planning phase through to the production and post-production activities of planetarium programs, while simultaneously fulfilling their International Baccalaureate community service requirements, which are a condition for graduation under the school's Diploma Program. Thus, both parties benefit from this unique collaboration, as the students gain valuable skills and experiences in project management, PR, and audio voice acting and recording, etc., while Expo Center reaps the benefits of the English language offering as well as helping to attract students, faculty, and friends of the volunteers.

II.2 Music Concerts under the Dome

In addition to the original seasonal production and other regular planetarium programs, as a new approach, Tsukuba Expo Center also utilizes the planetarium dome for special music concerts in evenings. The dome space offers a relaxing environment with comfortable seating and unique acoustics. The live music featuring local musicians is visually enhanced by optical and digital images and animation on the dome. Part of the concert is dedicated to a brief overview of the night sky with live explanation using the optical star ball, while the musicians provide musical accompaniment in the background. Featured musicians have included performers of classical, jazz, pops, as well as traditional Japanese instruments. One experimental collaboration featured a trio with piano, violin, and Japanese Shakuhachi (bamboo flute), under the planetarium night sky. Such events are thought to achieve a unique balance between arts and astronomy, and between entertainment and education.

Evening music concerts enable Tsukuba Expo Center to effectively appeal to a wider audience demography, including adults who are not available during the daytime hours, senior citizens, and residents who enjoy musical culture but may be less familiar with astronomy or science. This type of event can be an effective way to help a general audience become more familiar with astronomy and science. Furthermore, by featuring local musicians, some of whom are also research scientists or family members of scientists at universities and national laboratories in the area, we aim to further attract new visitors and also foster new collaborations with other science and education organizations through the planetarium operations. {Fig. 8}

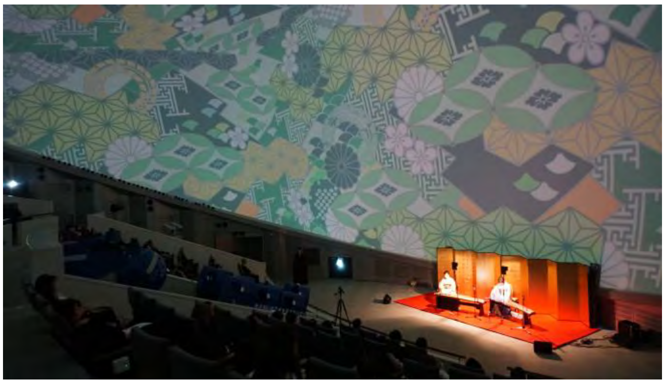

Fig. 8 – Evening Music Concerts under the Planetarium Dome

II.3 Science Outreach Activities

Finally Expo Center is leading outreach activities, utilizing a large, mobile planetarium that was constructed by the staff. More than 100 visits per year are made to schools and local communities, primarily for children and people who may have difficulty to visit to Tsukuba Expo Center directly. Furthermore, outreach visits are planned at hospitals, especially for children who are seriously ill. We hope to instill the children with a sense of hope and perhaps dreams of future career in science or in space exploration.

II.4 Seeking Additional Collaborations

Based on the success of this model, Expo Center is also planning to initiate collaborations with other organizations, including a space science venture business.

III. CONCLUSION

Tsukuba Expo Center is endeavoring to forge new collaborations within the community for achieving the goals of
1) Expansion of the number and diversity of visitors;
2) Mutual benefits for both parties through our collaborative activities; and
3) Demonstrate new avenues for creative and educational expressions of science and astronomy, in order to inspire a new generation of scientists.

ACKNOWLEDGMENTS

- We thank Tsukuba International School (http://tsukubainternationalschool.org/) for their great cooperation.

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- "*Planetarium wo Toshita Chiiki Renkei ya Kokusai Koryu no Torikumi*" (Planetarium Collaborations and International Cultural Exchange Activities), Daisuke Sato, Tsukuba Expo '85 Memorial Foundation, Japanese Council of Science Museums, Proceedings of the 24th Conference for Research Exchange, (17 February 2017), pp.55-66. [Japanese language]
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Spartan Young Astronomers Club: A format for youth programming

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Email: schmoll@pa.msu.edu

BIOGRAPHIES

Shannon Schmoll, PhD is the director of the Abrams Planetarium at Michigan State University. She is interested understanding how we can extend learning about astronomy beyond the dome and the many different ways we can use the full dome systems to teach about almost anything in the universe.

ABSTRACT

The Abrams Planetarium at Michigan State University in East Lansing, Michigan started the Spartan Young Astronomers Club in 2015. The program offers 2-hour programming once a month that includes custom dome content and hands-on activities for a nominal fee and is geared toward children 8-12. Each month has a theme in astronomy and includes basic night sky observing, cultural astronomy, spacecraft and more. It is run primarily by a set of core volunteers and some Abrams Planetarium staff. This program is now in its third year and we have learned several lessons and amassed a set of activities and custom dome content for use in other outreach contexts as well. This paper will explore the formation of the Spartan Young Astronomers Club, those lessons learned, and offer a framework for starting your own such club and will encourage people to brainstorm their own Young Astronomer sessions.

INTRODUCTION

The Spartan Young Astronomers Club (SYAC) is a monthly 2-hour program offered at Abrams Planetarium at Michigan State University (MSU) for children about 8-12 years old who have a budding interested in astronomy. It is based on the Cambridge Young Astronomers Club (CYA), which is part of the Cambridge Astronomical Association in Cambridge, England ("About the CYA"), though some modifications were made to utilize a planetarium dome every visit. The hope is to offer a wider variety of astronomy topics to younger kids to show them the wonders of the universe and encourage them to enter into the STEM fields, or at least appreciate the importance of STEM.

The program has a minimal fee to participate and is self-sustaining thanks to a core group of volunteers. It is held monthly on the first Saturday of the month and is open to anyone who shows up. We typically have between 15-30 students each month as well as their parents or guardians. Though the age range is roughly kids 8-12 year olds. Students explore a given topic for the month through an interactive dome program and 3 to 5 hands-on activities. We often try to send the kids home with something they can refer to later or try on their own at home.

I. FORMATION

The Spartan Young Astronomers Club was created after Renee Leone approached the Abrams Planetarium about partnering to deliver this program. She had experiences the Cambridge Young Astronomers Club with her son when they had lived in England. She found it fascinating and wanted to bring similar programming to Michigan State University and the planetarium was a natural fit.

Overall the goals and structure of SYAC are similar to the CYA. The main components of the program include hands on activities, a lecture or presentation, and a snack break. However, being at a planetarium, especially one with a fulldome system, has allowed us to incorporate the planetarium theater into our presentations and leverage its visualization capabilities. At the time of this conference, SYAC is near the end of its third year with plans to continue the program for many years to come. It is becoming a staple and cornerstone of the planetarium's programming and word of mouth has allowed us to continue to have a robust turn out each month.

II. PROGRAM DETAILS AND EVOLUTION

II.1 Target Audience

The goal of the Spartan Young Astronomers Club was to help students appreciate Astronomy in many different ways and beyond what they may learn in school through stricter adherence to the Next Generation Science Standards in the United States

(National Research Council, 2012). The hope is this can be a program that can encourage kids to stay in STEM and spark more interest and excitement.

Though ages 8-12 is our target age range we have had children, who have a particularly strong interest in astronomy, as young as 5 years old participate. We tend to skew toward the younger end of this range, though kids of all ages are well-represented. For hands-on activities we often split the students into smaller groups. When do this, we try to group kids of similar ages. We found this works better so young kids can focus on more basic information while older kids can go a little more in depth and neither age group gets bored from either over- or under-stimulated.

The original iteration of SYAC had students sign up for the whole year and we capped registration at 30 students as we felt this was a reasonable number for our volunteers to support with quality activities. What we found, though, was that most students could not make it every month as they had other activities they had to balance with SYAC on the weekends. As a result, after the first month or two, our numbers were consistently in single digits and averaged 4-5 students. From our second year onward, we dropped the cohort model and have made SYAC a drop-in program instead with no need to pre-register. So far this has worked in our favor, never really passing our original (and somewhat arbitrary limit) of 30 while also allowing more kids to participate without making a long term commitment. We now average around 20-25 student per month. Approximately half each month are returnees and about half are new visitors.

Parents are required to stay for safety reasons. As a result we set up a snack table that includes coffee and tea with some chairs for parents to wait. We do not expect or even encourage parents to participate as we want the kids to be able to explore science on their own. Despite this, many parents are actually interested in the topic themselves and can get quite engaged particularly in the planetarium portion of the program.

The program is offered monthly and lasts approximately two hours. We schedule SYAC for the first Saturday of the month from 10am-noon. We only offer our program November-August as we are in the middle of a large American university where the campus is overtaken by football related activities each fall, forcing us to only do SYAC 10 months out of the year. The planetarium itself is usually closed in August for maintenance. As a result our August program is a field trip to another location. Last year we were able to acquire discounted rates for SYAC students to visit our local science center and this coming year we will be visiting and doing solar observing with a small amateur observatory 20 minutes from MSU.

Each month we have a specific theme that we focus on. We choose the year's themes for the entire year ahead of time and posted on our website so people can prioritize which months they come. See Table 1 for a listing of 2017-2018 themes and a

II.2 Program Structure

Table 1 List of 2017-2018 SYAC Themes

Month	Theme	Description of What Was Covered
November	Moons around other Planets	We toured solar system moons, explored internal structure of the moons, discussed center of mass and orbits, and reproduced Galileo's observations of Jupiter's moon.
December	Humans and Light	We focused on light pollution, its effects on how well we can observe the night sky, and strategies for abatement
January	Astronomy Superheroes	We talked about well-known astronomers, astronomers from underrepresented groups, and the various STEM careers that help big astronomy happen
February	Visit from Science 4 All	We had a local group that encourages students to create science experiments and exhibits and then teach other children science. They did some physics experiments with SYAC kids while we related it to astronomy examples in the dome.
March	Everything Spins	We explored all the different ways astronomical objects spin from rotation to revolution. We also explored rotational physics and face-locking of the moon.
April	Weird Telescopes	We explored various detectors and telescopes that are not the standard reflectors and refractors and where they are located. This included IceCube, ALMA, and LIGO.
May	What Would Alien's Breathe	We had to cancel this one this year, but we would have looked at moons and planets with atmospheres, their compositions, and explore how they would feel compared to Earth's atmosphere.
June	Space Volcanoes	We explored the different ways volcanoes form and the types of volcanic activity. Then explored examples in the solar system and their similarities and differences to Earth.
July	Debunking Astronomy Urban Legends	We are exploring common misconceptions and some of the major misinformation campaigns such as the moon landing hoax and flat earthers.
August	Visit to Fox Park Observatory	We will be taking students to a local amateur observatory for a tour and do some solar observing while there.

short description of what we covered. We try to pick a variety of themes that would entice people from different angles to appreciate astronomy and look at the universe at different scales. The overlap, so far, has been fairly small though we do find ourselves revisiting certain ideas in a slightly different context. For instance, we have revisited the idea of center of mass several times when talking about planets and their moons as well as discussing how everything spins and orbits. Since it we know students need some level of repetition in learning new ideas, this is a desirable feature and helps reinforce what they are learning in SYAC ((Bransford & Schwartz, 1999).

The two hours of SYAC are generally broken down in a similar manner each month. Most students arrive shortly before 10am and pay the fee at the cash register and get a sticky name tag they can decorate and wear. This helps us identify and call students by name during activities and acts as their "ticket" or sign they have checked in.

We usually begin in the planetarium for a 30-45 minute presentation introducing that month's topic. This program might include flying to various objects in the solar system or Milky Way, showing fulldome images or 360 photospheres of observatories, discussing spacecraft using 3-D models, talking about apparent motions in the night sky, finding constellations, or whatever else is appropriate. We make these sessions interactive and ask the students a lot of questions about that they think or know about a topic already. This helps engage them in the topic as well as activate prior knowledge they might have on the topic (Piaget, 1970). We keep this fairly informal as well so students can ask questions and we can go off on tangents to ensure that students have some element of choice and control in their learning. Having control in one's learning and following the intrinsic interest of the students will help them feel motivated to continue learning (Falk, Dierking, and Adams, 2006). The informality also means that the prep work on our end is minimized, making it easier to create essentially a custom dome presentation each month. However, this does require someone who is very comfortable with running the planetarium system on the fly.
After the dome presentation we usually have a break where we offer some healthy snacks for students. We provide water, granola bars, and cheese crackers or something similar. We do usually get things that can store for a few months at least so nothing goes to waste.

Once snack is done, we will have several hands-on activities set up as stations around the planetarium lobby. Students spend roughly 15 minutes at each location and then rotate. If we have larger groups that month, we will split the groups into 5-6 students each. With smaller turnouts, we have one group move all the students together. These activities are generally run by our volunteers, though we have also brought in special guests on occasion. Special Guests have included the Abrams Planetarium meteorite collection coordinator, Physics and Astronomy Professors, and members of the local astronomy club.

The activities that we do at each table depend and relate to that month's theme. Activity types have included art projects, games, kinesthetic models, demos, experiments, data collection and analysis, or even additional time in the dome if appropriate. When possible, we also try to send students home with something that allows them to continue learning. For example, one month's theme was "Everything Spins" and we did several experiments with fidget spinners that students were able to take home. We also did a playdoh volcano demo and sent student home with their own small tub of Play-Doh for our "Space Volcanoes" theme.

Though we almost always start in the theater to introduce a topic and then do the activities, we also keep things flexible. Sometimes it does make more sense to explore a topic with hands-on activities and then go to the theater to explore examples in space. See Table 2 for sample agenda from our "Everything Spins" SYAC session as well as images from the activities.

II.3 Planning Process

Our program runs with a core group of volunteers and myself. We plan each month starting about 3 weeks in advance. We do this over email where we are reminded about that month's topics and the learning goals we have for that month. We start with what we will be able to cover in the theater using our system and built hands-on activities around that.

Sometimes hands-on activities are created specifically for SYAC, especially any games that are made to explore a topic. We will also search trusted websites for ideas that we will modify to fit the format of SYAC. A possible agenda and order of activity to dome content is suggested and revised as necessary and as assign activities to each volunteer. Each person is responsible then to testing and preparing the activity. Our volunteers are made of science educators and enthusiasts who have an interest in outreach. Including myself and planetarium staff, we have a high school student, a few undergraduate students who have an interest in education, and two adults who have a strong history of informal science education.

Table 2 Samples Agenda from the "Everything Spins" SYAC

Activity (time)	Description	Picture
Dome (45 minutes)	We started at Earth and talked about how it rotated, how it orbits the sun, and the moon orbited the Earth. We visited Mars to discuss Phobos and Deimos and show how Phobos appears to go backwards due to its fast orbital speed. We looked at conservation of angular momentum in relation to solar system formation and why the planets are in a disc shape. We visited binary stars to show the different ways they orbit each other We looked at the Milky Way and talked about stellar orbits and density waves and why the arms are not winding up We looked at SDSS data to talk about orbiting galaxies in clusters and superclusters	N/A
Snack Break (15 minutes)		
Activities (1 hour total) Groups of 6 rotated every 15 minutes		
Moment of Inertia	We had eggs boiled for 0, 5, and 15 minutes. Students then spun the eggs to guess which was which and test their prediction by smashing the eggs. This was related to the moment of inertia and studying the internal structure of planets.	
Conservation of Angular Momentum	We had students explore conservation of angular moment using a spinning chair and holding weights at different distances. We also did this with a spinning bike wheel.	 

Fidget Spinner and Gyroscopic Stability	We also had students test similar ideas to conservation of angular moment with fidget spinners. We also explained gyroscopic stability using one hanging from a string. Students were able to take a fidget spinner home.	 
Kinsthetic Moon Activity	Students explored how the moon is face-locked and what that means for its rotation by going around the large globe in our lobby by not spinning and then spinning.	

II.4 Funding Model

Since this program is run almost entirely by volunteers or salaried staff of Abrams Planetarium, we keep costs very low and only enough to cover supplies and snacks for the students. This is because we very much want this to be something that is available to all kids and we try to not make it cost prohibitive. As mentioned above, our first year was a cohort of 30 students and we charged approximately $25 per student for the year and $40 for families with two or more kids. Once we realized this was not a viable model to have consistent participation, subsequent years have turned into a drop-in style program where we charge $3/participating student.

We also offer a yearly SYAC membership at the original prices of $25 -$40 for the year. Our "membership" card is a nicer conference style name tag they bring with them each month. Overall, if people buy the membership, it is only worth it if it bought at the beginning of the season and they plan on coming almost every month. As a result there is consideration being made to eliminate this option. However, Abrams Planetarium does offer a yearly membership that allows people to come to regular planetarium shows for free along with other benefits. As SYAC is becoming a consistent cornerstone of Abrams programming, it may make sense to offer SYAC as a benefit of regular Abrams membership instead, perhaps at a new level of membership than we currently have.

The cost to us varies month to month depending on needed supplies for activities. Some months we have spent $0 and others are closer to $100. However, on more expensive months, the supplies we purchase can often be reused at future SYAC events or outreach activities, making sure that nothing goes to waste.

III. ADDITIONAL BENEFTIS OF SYAC

We have plans to expand our regular K-12 programming at Abrams Planetarium to include hands-on activities that can help extend learning beyond the theater. This can be a value-added piece for visitors who come for field trips and have higher needs of justification of cost and time away from school in the United States. The hidden benefit of SYAC is that we can test topics, experiments, activities, and themes that could be expanded into these hands on activities. This allows us to expand our offerings continuously while also working out kinks.

IV. CONCLUSIONS

SYAC has been an exciting and engaging program we have added to the repertoire of Abrams Planetarium. There seem to be endless topics to explore with students and they always seem eager to learn more. This could be a great way for other planetariums to expand their programming and explore further how to engage young students both in and out of the dome and well as build a repertoire of hands-on activities for various occasions.

ACKNOWLEDGMENTS

I would like to thank Renee Leone for coming to me originally with the idea to create this program. She is also the founder of the MSU Science Festival, another amazingly great science outreach event we participate in and her endless support of science education is making the world a better place. I also want to thank Bryce Kobe and Roxanne Truhn for their continued support of SYAC from the beginning. Other fantastic volunteers who have been helping with more activities in the past year are Huei Sears, Jessica Ranshaw, Jonathan Sheehan, and Craig Whitford. Also, big thanks to Rebecca Hatt who took on my usual SYAC role while I am at IPS presenting this paper on SYAC.

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Mission Investigation!

Shared Learning with Your Public

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BIOGRAPHIES

I hold a B.S. in Astronomy and a M.A. in Science Education. I spent eight years in industry before beginning my career as a teacher in 1998. I have been at the Howard B. Owens Science Center planetarium for 25 years, 18 as full-time staff.

ABSTRACT

In the Fall of 2017 I took on an ambitious series of programs for my public presentations, held once a month. I entitled the series: "Mission Investigation!" and chose to study Mars in October, Jupiter in November, and Pluto in December, highlighting the scientific missions that bring us information about these solar system favorites. This was ambitious because I am in no way an expert on any of these topics, and didn't want to "fail" my public. Then I remembered, I don't HAVE to be the expert! I designed these programs to be a shared experience, allowing the public to participate in activities and learn alongside me the wonders of these planets! In this session I'll share my procedure and successes.

INTRODUCTION

In order to develop interactive public programs on Mars, Jupiter, and Pluto, I relied heavily on NASA resources in the form of images and data. I specifically used information available on the websites solarsystem.nasa.gov and spaceplace.nasa.gov. For each public program, I set up a variety of activities developed from NASA activities for the public to explore for a half hour prior to the actual planetarium presentation. The planetarium presentation was usually between one and one and half hours long, allowing for questioning and a tour of the night sky. In each program, I provided the audience with materials that enabled them to share in the learning experience, and at times, become the experts themselves! My public programs typically bring in families with children as young as three years of age, so I carefully planned activities that I felt would include everyone.

I. MARS

I.1 Pre-Program Activities

To engage my younger audience, I provided Mars coloring sheets. For a slightly more challenging coloring opportunity, I provided a sheet with an outline of a person, and information about the planet so that the artist could design what they would need to wear on the planet (Figure 1). I printed fun facts about Mars and the various rover missions and posted them all around the room, and created a scavenger hunt of questions that could be answered from the printed facts. My volunteers collected the completed scavenger hunt papers so we could award prizes at the conclusion of the evening.

Figure 1 – Draw Me! – Pre-Program Activity Sheet

I.2 Planetarium Lesson/Activities

The planetarium lesson began with an observation of Mars in the night sky, and progressed forward in annual motion to observe the retrograde motion. We then brought up a visual to explain retrograde motion. Next, we integrated the arts by playing a musical selection, the Mars movement from Holst's Planet Suite, showing images of Mars while the music played. There were no labels to the pictures, no explanations, no talking; this was merely intended to provide an overall wonder for the planet through music and visuals. After this segment, we shared knowledge of Mars by bringing up images and having the audience hold up a picture showing whether the image came from an orbiter or a rover. We had "experts" in the audience share the Top 6 Discoveries of Mars by reading the materials that came directly from the NASA website. We concluded the evening by returning to the current night sky, exploring planets and constellations visible.

II. JUPITER

II.1 Pre-Program Activities

As with the Mars program, coloring sheets were made available, this time relating to Jupiter. Sample artwork was displayed, showing how Juno images from Jupiter inspired artists (Figure 2). We had several stations set up around the room, including an activity called "Dunking the Planets" where you used different fruits to represent the planets to determine which ones sink/float (a density lesson). We had a scale where you could weigh yourself and determine your weight on other planets. "Mystery balloons" had different materials inside for the participants to guess, representing the objective of the Juno mission to determine the "insides" of Jupiter. Glitter jars were set up to simulate storms on Jupiter. A thermometer was placed inside a two liter bottle which had a pump to increase pressure to demonstrate the relationship between temperature and pressure.

Figure 2 – Jupiter-Inspired Artwork
Image Credits: NASA/JPL-Caltech/SwRI/MSSS/Mik Petter

II.2 Planetarium Lesson/Activities

For this program, I took on the role of the Roman goddess Juno for the entire presentation. I began using the planetarium orrery to demonstrate "how I got to my husband Jupiter" by considering how the constant motion of the planets affects the planned trajectory of a spacecraft. I mentioned the many moons surrounding Jupiter, and went around the room asking to see which moons each person represented, making sure to tell Ganymede, Callisto, Europa, and Io that I was keeping a close eye on them! Then I provided "a glimpse of why my husband is so wonderful" by presenting images of Jupiter set to music. I pointed out the close conjunctions of the planets in the morning sky that happened to be close to the date of the presentation (October 17, 2017). I forwarded to January 8, 2018 to show the close conjunction of Jupiter with Mars. We brought the lights up to look at images and also to ask volunteers to share improvisation stories on "How I came to be" and "What's inside my Body." We related this to the mission of Juno, and asked the six different audience members who had been given the appropriate cards to read information about the spacecraft. After discussing the mission, we turned to the night sky and I guided them through the planets and constellations that would be visible, as well as highlighting the Leonid meteor shower.

III.PLUTO

III.1 Pre-Program Activities

As with the programs highlighting Mars and Jupiter, coloring sheets on Pluto were made available. One activity sheet asked for the participant to draw what they thought the surface of Pluto should look like, at a distance of 40 times further away from the Sun than the Earth. We had a fundraiser for the planetarium, asking people to make a donation in order to vote for Pluto's status after reading information about Pluto and the definition of planet and dwarf planet (Figure 3). Activities included creating a flip book comparator to represent the discovery of Pluto and making a model of the Pluto/Charon system to demonstrate the location of the center of gravity is between the two planets.

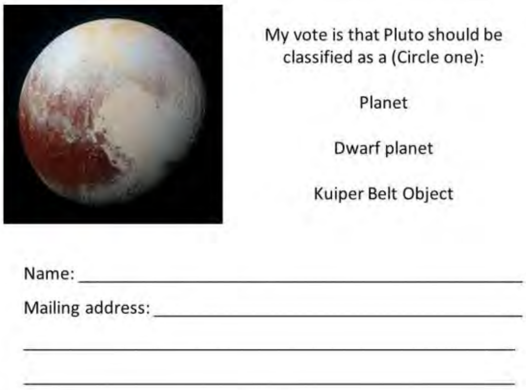

Figure 3 – Pluto Status Ballot

III.2 Planetarium Lesson/Activities

We began the program by observing images from the New Horizons flyby of Pluto, briefly discussing characteristics of the planet to show how surprising the discoveries were to scientists. We then toured the night sky to locate deep sky objects, and then observed images of these objects at different wavelengths in order to understand the importance of creating scientific images which observe at these varying wavelengths. We considered the future of the New Horizons mission as it heads out to explore the Kuiper Belt Object 2014MU69. We returned to the early morning sky to identify planets, pointing out the location of Pluto in the sky. While this portion of the program had fewer shared learning activities as compared to the Mars and Jupiter programs, I always make sure that the audience remains involved through question and answer techniques.

CONCLUSION

You don't have to be an expert to facilitate a love and wonder for science in your audience. I demonstrated here creative ways that I use easily accessible information from NASA websites to allow the audience members to share in the learning experience by becoming temporary experts or even impersonating moons! I find that if you demonstrate a love for learning, you can pass that on to all that attend your programs!

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To Tell a Story

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BIOGRAPHY

I hold a B.S. in Astronomy and a M.A. in Science Education. I spent eight years in industry before beginning my career as a teacher in 1998. I have been at the Howard B. Owens Science Center planetarium for 25 years, 18 as full-time staff.

ABSTRACT

Can just anyone tell a story (in the planetarium)? Why and when should you use stories in your programs? How do we stay focused on what is really important? For this portion of the presentation, Patty Seaton will share the traditional Greek story of Perseus, Medusa, Cassiopeia, and Andromeda, modeling storytelling techniques presented by Toshi Komatsu earlier in the session.

INTRODUCTION

Sometimes the story you want to share in the planetarium is simply that – a story. A myth, a legend. While you want to be true to the culture that originally told the story, you can also incorporate the "rule of three" elements that Toshi Komatsu just described. I would like to re-tell the Greek story of Perseus, Medusa, Cassiopeia, and Andromeda, outlining what I call the "soap opera in the sky". Note that I prompt the audience for input; their expected response is in parenthesis in the text below. Needed visuals on the dome are indicated in brackets.

I. PERSEUS AND MEDUSA

[NOTE: Sky should be set for the fall, with Cassiopeia, Andromeda, Perseus and Pegasus all in the sky. Display outlines of the figures as indicated, where available.]

Perseus can be found here in the sky [draw using laser pointer, then show the outline as available. Leave on during this part of the story.] Perseus was the son of Danae, daughter of King Acrisius, who had locked Danae away because of the Oracle that Danae's son would one day kill him and become the next king. But trying to interfere with prophecy never works, and Zeus himself visited Danae which therefore led to the birth of Perseus. Perseus grew to be a strong fighter who was willing to take on any challenge. King Polydectes challenged him to bring him the head of the gorgon, Medusa!

Medusa had her own problems. She had once been a beautiful woman, but made the mistake of going on a romantic date with Poseidon in the temple of Athena. Athena turned her into a hideous creature who had what in place of hair? (snakes) and if you looked into her eyes? (you'd turn into stone). Killing her would be a problem! Fortunately, Perseus had the blessing of Zeus and Athena… he was given the gift of a sack for Medusa's head, winged sandals and an invisibility hat. However, even while invisible, Perseus couldn't look directly at Medusa, so Athena gave him advice, to polish his shield. What good would that do? (It can be used as a mirror). So Perseus used the reflection of Medusa in his polished shield to cut off her head. Her blood pooled on the ground, and swirled in a strange form… a full-sized stallion with eagle-like wings! This was the birth of Pegasus, the first winged horse, which can be found here in the sky, by identifying this square. [Point out, and then show outline as available.] Perseus took Medusa's head and placed it carefully in the sack, then fled the cave where he had found her in fear of being discovered by her two gorgon sisters.

We pause this story here, to introduce another cast of characters… [Fade the constellations of Perseus and Pegasus]

II. CASSIOPEIA AND ANDROMEDA

In Africa there was a kingdom known as Aethiopia. It was ruled by King Cepheus [point out and show outline as available] and Queen Cassiopeia [point out and show outline as available]. The queen was very beautiful, but that turned out to be her fatal flaw. Her beauty led to her vanity. She would boast of being more beautiful than any other woman. And one day, she went too far. She boasted that she was more beautiful than the Nereids, immortal sea goddesses. It is NEVER good for a mortal to insult the immortal, so the Nereids complained to Poseidon who therefore decided to punish Aethipoia. He vowed to send a horrible sea monster to destroy everything and everyone. Queen Cassiopeia pleaded for mercy, but it was too late. When she accepted responsibility for her actions and pleaded to save her city, Poseidon relented a little (what does *relent* mean?) and gave her the awful solution to offer her daughter, Andromeda, as a sacrifice to the sea monster in order to save her city. What choice did she have? The dreaded day came, and Andromeda was chained to the cliff. [Point out Andromeda and add outline as available.]

III.THE STORIES COME TOGETHER

Here's where our stories collide. Let's bring back Perseus and Pegasus. [Add outlines as available.] The earliest versions of the stories have Perseus flying using his winged sandals. More modern versions of the stories (the original; 1970s movie of "Clash of the Titans") have Perseus flying on Pegasus. In either case, he happened to fly over the kingdom of Aethiopia on the day that Andromeda was chained to the cliff. He knew nothing about the story of Queen Cassiopeia, but one look was all he needed to see that Andromeda was in trouble. And that she was beautiful. And he thought, hey, maybe if I rescue this girl, I can go on a date with her! He saw the monster coming, and tried to distract it. The monster looked up, Perseus whipped out the head of Medusa And… (the monster turned to stone!). [NOTE: here is where I put on my Medusa hat and shine a light on my face. The students are usually pleasantly startled by the unexpected use of this prop!] Therefore, the monster was destroyed, Andromeda was saved, and not only did Perseus get to date Andromeda, he got to marry her! And they lived happily ever after… OR you can add the story of how Andromeda's original fiancée, Phineas, decided to challenge Perseus and then gets killed by him… OR you can make up this ending, how Andromeda gets on Perseus's nerves, so he dumps her off on a deserted island and flies off on Pegasus. [Note: the kids seem to like this version!]

The idea is to make the story dramatic. I probably never tell it precisely as I had to write it down in words. I tell students that in appreciation of Dionysus, the god of wine, storytelling often took place along with much drinking of wine, so should we expect the stories to be told the same way every time? (NO!) Therefore (hey look, another of Toshi's rule of three for the Sentence!), the stories vary and SHOULD vary, and in my opinion, be told with a bit of dramatic flair!

ACKNOWLEDGMENTS

Thanks to my co-presenters, Toshi Komatsu, and April Whitt.

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For kid-friendly versions of the Greek stories, especially for students familiar with Rick Riordan's Percy Jackson series, I recommend *Percy Jackson's Greek Heroes* by Rick Riordan, illustrated by John Rocco. Disney Hyperion, 2015.

Exploring the Universe: Unscripted Live Shows in the Planetarium

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BIOGRAPHIES

Talia Sepersky is the Planetarium Coordinator for the Charles Hayden Planetarium at the Museum of Science, Boston. She has been at the Planetarium since 2011, and has additionally served as the treasurer/membership chair for the Middle Atlantic Planetarium Society since 2017. She is also a serious and unrepentant nerd.

ABSTRACT

At the Museum of Science, Boston, we offer unscripted live shows on a regular basis. We rely on audience participation and presenter preferences to choose topics and destinations. Not only does this allow repeat visitors the chance to see the show multiple times without having to see the same show twice, it lets us take full advantage of the capabilities offered by a digital planetarium. It provides greater opportunities for engaging the audience and for adapting the show to keep it up-to-date and to suit the audience. As a result, our live, unscripted show has an attendance far above our other shows.

INTRODUCTION

In the Charles Hayden Planetarium at the Museum of Science, Boston, we regularly offer a 45-minute unscripted live show called "Explore the Universe". During the school year this show generally runs once or twice a day on weekends, and it will run once or twice a day every day during school vacations. Having these shows be unscripted creates a unique set of challenges, but we have found that putting in the effort to overcome these challenges has allowed us to create a show that resonates deeply with our audiences, provides a maximum educational punch, and entices audiences to return and see planetarium shows in the future.

SHOW STRUCTURE

Staffing

Since the unscripted nature of the show requires that the presenter be able and ready to "think on their feet" and react instantly to audience questions, suggestions, and requests, and that the show go to any number of possible destinations, we have found it best to have two staff members per "Explore" show. One is the designated presenter and does the majority of the talking during the show. The other serves as the pilot and controls the digital planetarium software live. While it can be possible for a single staff member to serve as both roles if necessary, we have found through experience that a better show will result if the presenter can focus on audience interaction and content, without having to worry also about controlling the digital system.

Content

To provide our audiences with a sense of context, all our shows begin on Earth with a daytime sky, move to a nighttime sky, and follow with an Earth liftoff. They generally end at the edge of the visible Universe. Between those two points, the content can vary wildly depending on the presenter's preferences, current events, or audience requests. Generally, though not universally, we will visit a planet of the Solar System (audience's choice, voted on by applause, unless there is something newsworthy or significant happening at a particular planet), look at a Solar System overview, talk about something extrasolar (popular topics include star formation and exoplanets) before moving outside of the Milky Way to look at the entire galaxy. To end, we use various galactic datasets to provide an overview of the visible Universe before flying home to Earth to end the show.

Since the show is live, there is no set end time. We try to end the show 40 minutes after we begin it, but usually it runs closer to 45 minutes (there is, after all, a whole lot of Universe that can be talked about).

OVERCOMING CHALLENGES

Staffing (Again)

Unlike our pre-recorded shows or our live constellation show, which require only one staff member to run, we usually use two staff members to run an "Explore" show, one to be the primary presenter, one to be the pilot. This, of course, can place a burden on a planetarium staff that is short-handed or, as is often the case in our offices, requires staff time to be devoted to other projects.

To help ease this burden, our staff has some members for whom presentation and theater operations are treated as a specialty. While our entire staff, including our show production staff, work the shows, it is helpful to have some staff members focused more on the education side to take the bulk of the presentation work. This allows the remaining show shifts to be more spread out amongst the production staff, allowing them to participate in the live shows while still having time for special projects and show production.

Even when our staff has been taxed to its limit, there has never been a question of discontinuing this practice of having two staff members running the "Explore" show. We make this effort because we have found the increased staffing requirements to be entirely worth it, for reasons that will be outlined in a later section.

Content (Again)

Presenting an "Explore" requires a lot of knowledge. Allowing the audience to choose topics or destinations requires that the presenter have at least a little to say about each of those possible outcomes. We have to be able to talk about any planet, or be prepared to switch topics if the presenter is discussing one thing but the audience expresses interest in another. It also requires remaining up-to-date as much as possible on all areas of space science.

One way to manage remaining current is to have one or two staff members who make a point of staying informed on events in the realms of astronomy and space exploration. These staff members then make certain the remaining staff have at least a general idea of what is happening in the Universe. I have found the website *Portal to the Universe*[1] particularly helpful in this respect. This site gathers press releases from global space agencies and science institutions and does a headline roundup of all the major space news sites and astronomy bloggers.

This particular challenge is also where having two staff members in the show can be extremely handy. With two people in there, neither has to be knowledgeable about everything. As long as one of them has *something* interesting to say to the audience about the most likely topics to come up, your bases are covered.

There is, of course, also the perfectly acceptable and highly encouraged option of admitting that one does not know everything about space. The Universe is, as previously mentioned, kind of vast.

BENEFITS OF THE UNSCRIPTED FORMAT

Staffing (Once More With Feeling)

Training a staff to do unscripted live shows is not easy, nor is it a fast process. Each of our staff members had to learn a great deal on a great number of space topics, how to live fly our planetarium system, how to have an effective interaction with an audience, and how to jump between topics. That said, having managed this, our planetarium staff now has maximum flexibility when it comes to creating and running shows. At any given time any member of our staff can step in even at the last minute to present or fly a 45-minute live show covering any number of space subjects either for the general public or for school groups with more specific requirements.

As previously mentioned, having two staff members in the show allows the presenter to focus more entirely on audience interaction and education, while the pilot can focus on the smooth running of the planetarium system. We have also found that having the pilot in the room and giving them a desk microphone will increase the likelihood of audience interaction. Presenter-pilot interaction and banter is more likely to make a reluctant audience participate in the presentation themselves than simply having the presenter speak alone. Presenter-pilot banter can also be a source of entertainment for the audience. In the inevitable cases where the audience simply refuses to participate, having the pilot there gives the presenter someone to talk *to*, as opposed to spending the entire show talking *at* the audience.

Unique Experiences

A devotee of the Charles Hayden Planetarium could, during a school vacation week, see seven different "Explore the Universe" shows with seven different pilot-presenter pairs interacting with each other and the audience in different ways, visiting different planets, covering different topics, and all-around providing seven fairly unique experiences. Many visitors return to the Planetarium to see this show multiple times. The ability to adapt the show also allows us to maximize the impact of every planetarium's primary mission: education. Staying up-to-date on the state of space science allows us to give our audiences an accurate view of current astronomy and space exploration while also providing them with overall view of the Universe at large.

The ability to adapt on the fly has proven especially useful for attracting school groups. We can, to a certain extent, adapt shows to suit a school's particular curriculum (the extent to which we can adapt an individual show is, of course, dependent on how many school groups are in each one). Giving teachers support for their specific curricula is always helpful for them in arguing why a visit to a planetarium is a worthwhile field trip expense.

As a fringe benefit, the fact that the shows are not all the same stops our staff from becoming bored with this show. It also allows each staff member to strengthen their own skills as presenters and pilots by watching each other and learning from each other's' skill sets.

Longevity

The unscripted format of "Explore" ensures it will never be out-of-date. It will never need to be switched out for a more current show or script. Since the Charles Hayden Planetarium reopened after a major renovation in February 2011, it has run various shows repeatedly, swapping various shows in and out of the schedule depending on how long they have been running. The singular exception to this is "Explore the Universe", which has been run continuously since the reopening. There has been no need to retire or rest this show, since it is always changing and updating itself and its popularity has never flagged.

Popularity

"Explore the Universe" is, despite having been in the schedule uninterruptedly for over seven years, by far our most popular show. On weekends and during school vacation week it sells out faster and more frequently than any of our other offerings. During FY2017 and the first three quarters of FY2018 our most popular pre-recorded show ran twice as many times as "Explore" and still did not match its attendance numbers.

Fun

Getting to pick a planet to visit is fun. Getting to ask that question you've always had about black holes is fun. Getting to fly from the edge of the visible Universe to Earth is fun. Getting to hear your presenter make jokes and trade *Star Trek* vs. *Star Wars* cracks with your pilot is fun. The structure of an unscripted live show can be massively entertaining for the audience. Additionally, when the presenter gets to talk about their favorite subjects, as opposed to those mandated by a script, the *presenter* will have more fun. This enthusiasm will invariable be apparent to the audience, who will, as a result, have a more positive, unique experience.

CONCLUSION

Unscripted live shows require a greater amount of time and effort on the part of a planetarium staff, both in the training phase and the actual running of the show. But we have found that the benefits, both tangible (greater attendance) and intangible (greater audience and staff satisfaction), are so great that the Charles Hayden Planetarium's unscripted live show "Explore the Universe" is the only show we've run that we have never retired, rested, or replaced, nor have we ever even considered doing so. It has become a Boston favorite and has assured itself a continuous place in our planetarium offerings for any foreseeable future.

ACKNOWLEDGMENTS

I would like to acknowledge the staff of the Charles Hayden Planetarium for their awesomeness in general.

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Fatal flaws: I'd love to licence this film but ...

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BIOGRAPHIES

Dr Jenny Shipway has been involved with planetaria since 2003, including managing the 17m Winchester Science Centre planetarium for its first ten years. She sits on the IPS Education Committee, is a trustee of the Spacelink Learning Foundation and a former president of the British Association of Planetaria.

Kaoru Kimura has been involved with planetaria since 1987. She works for E/PO of Astronomy Education and program coordination. She engages in work to relate formal education, non-formal education to a research organization. She sits on the IPS Education Committee, and has been helping with the LIPS workshop for several years.

ABSTRACT

Fulldome films are expensive to produce, but there are a limited number of planetariums seeking to licence shows. This demands that films are licenced internationally, bringing complex challenges related to different cultural expectations and requirements. We have all seen shows that are fantastic except for that one fatal flaw that makes them unplayable in our dome.

In this session, participants share the common issues which have prevented them from choosing shows that would otherwise have been of interest to their audiences. The resulting knowledge will be made available to producers and the planetarium community; please contact Jenny Shipway for a copy of the report.

EXAMPLES FROM THE UK

Some examples of such issues as encountered by Jenny Shipway, who spent 10 years licencing shows for UK audiences:

For children under 8yr, it is necessary for us to portray a rather idealized world. This means avoiding any cruelty and to clearly show that ‘bad’ actions directly result in poor outcomes. Characters who do ‘bad’ things must learn why this was wrong by the end of the show. The thought is that the children will copy behavior they see on-screen. A child climbing out of their bedroom window without immediate harm would be bad, while climbing out of a spaceship is fine because it cannot be copied.

Physical stereotypes based on unchosen traits should be avoided. Things like the clever child wearing glasses, the girl being scared, the evil person having a disability/disfigurement, the scientist having wild hair, the hero being taller, the stupid character being fat, the good person being blonde. Challenging these stereotypes (ie having character/physical combinations that are less often seen in media) makes a show very attractive.

Gender balance is important. Research has shown that there is positive impact for girls to see female STEM role models, while there was no measurable difference for boys. If you have two characters, then one must be female. Female narrators are preferred. Where both genders are present, it is important that the female character is not seen as less able.

In the UK, we have the advantage that almost all shows can be provided in our own language. However, the quality of translation and narration varies wildly. As the time-cost of re-scripting/recording is significant vs a single licence fee, those shows which would require this treatment are much less attractive than those which are ready to play. There are examples where translations have significant and distracting grammatical errors, but also where the sense of the science communication is lost (eg where a word may be considered difficult/jargon in one language but not the other).

Astronomy For Very Young Children

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BIOGRAPHIES

Linda Shore, CEO of the Astronomical Society of the Pacific spearheads the society's education initiatives in support of ASP's mission to improve scientific literacy through astronomy. She was also the Director of the Exploratorium Teacher Institute and is the co-author of several activity books for children, families, and adults.

Anna Hurst, Director of Museum, Park, & Library Programs, Astronomical Society of the Pacific, is Project Director for *My Sky Tonight* (*MST*), bringing pre-school astronomy experiences to museums. She has worked at the ASP since 2005, creating professional development programs and hands-on astronomy materials for museum educators and park rangers.

ABSTRACT

Six years ago, the *Astronomical Society of the Pacific* (ASP) asked a very provocative question: *Can very young children (aged 3 - 5 years) learn astronomy – and if so – what kinds of concepts can they comprehend and can astronomy be used to develop age appropriate science thinking skills?* With five years of funding from the National Science Foundation's Advancing Informal Science Learning (AISL) division, the ASP collaborated with experts in early childhood development, informal learning, and evaluation to conduct a five-year research and development project. This project (*My Sky Tonight: Early Childhood Pathways,* or MST) is in its sixth and final year, after a timeline and scope expansion enabled by supplemental funding from the NSF. The goals of the MST project are to: (1) Advance the knowledge base concerning the astronomy conceptions and curiosities that children have in their early years, and how these can be built upon to position children for later scientific understanding as they grow. (2) Develop interactive learning experiences to be used by museum educators (and parents and other adults in children's everyday lives) enabling young children to progress to increasingly sophisticated levels of astronomy concepts and scientific reasoning, providing a foundation for lifelong learning about astronomy and about science in general. (3) Increase participation in astronomy of families in general, and specifically underserved families by engaging minority groups in formative development of the deliverables, delivering culturally relevant content, and targeting underserved groups as end audiences. (4) Improve practice by engaging informal education practitioners in research, co-learning, and the development of effective practices, and providing them with the tools and the support they need for implementation. In this hands-on, interactive session, we will (1) describe the interactive research and design process used to successfully develop a suite of preschool level activities designed for museums, planetariums, and other informal learning settings, (2) show videos of young children engaged in a selection of the astronomy activities and discuss our key observations, (3) present results from the MST research, and (4) engage session participants in sample preschool level astronomy activities and share our ideas for next steps, which include investigating the role of using storybooks in combination with our science-rich MST astronomy activities for young children to support engagement in science practices.

I. INTRODUCTION

I.1 A Crazy Idea

The ASP has had a long and successful track record of developing astronomy-related activities, materials, and resources for informal learning venues. We have also been at the forefront of providing high-quality professional development to informal science educators to help them bring engaging astronomy experiences to their public audiences. Since 2005, over 500 science centers, planetariums, libraries, state and national parks, nature centers, and children's museums have participated in ASP professional development programs and received kits of astronomy-focused activities. Today, these institutions comprise the ASP's network of like-minded, informal learning organizations (*Astronomy from the Ground Up, or AFGU*), each dedicated to wanting to improve their ability to use astronomy to support science literacy.

The astronomy learning experiences and materials we produced for these informal learning venues were developed to support older children, pre-teenagers, and families. Yet increasingly, members of the AFGU network were asking us to develop age appropriate astronomy experiences for their very youngest visitors – children in preschool and early elementary grades. A needs assessment of the AFGU network conducted in 2012 revealed that 92% of the respondents were interested in learning how to introduce pre-school children to astronomy. So we began to consider an idea that many of our closest colleagues in the field thought impossible to accomplish – could we create developmentally appropriate astronomy activities for children between the ages of 3 and 5 years? Was it possible for young children, still in the early stages of developing basic thinking skills, to engage with astronomical ideas requiring an ability to think abstractly and use multiple fames of reference? And if it were possible to create opportunities for young children to engage with astronomy, how would one even go about the process of developing, testing the materials, and conducting research on an audience that was barely verbal? Finally, what would educators need to know to facilitate activities on their museum floors, inside their planetariums, or at other informal venues?

I.2 The *My Sky Tonight* Project

In 2011, we assembled a team of renowned experts in early childhood development, informal learning, and evaluation and began to pool our expertise to develop an initial plan for a design, research and development project. The team developed a project design that included the following elements: (1) creating a pilot set of early childhood level astronomy learning experiences for informal venues, (2) conducting evaluation research on the activities as they were tested with children in museums, (3) revising the activities and repeating the testing in informal settings, and (4) collecting and analyzing data to determine the impact that engaging in age appropriate astronomy activities has on the development of science thinking skills. All activities were created using the principles of "developmentally appropriate practice," described by the National Association for the Education of Young Children (NAEYA, www.naeyc.org). Young children learn through play and exploration and what they learn varies across ages, individual interests, and their unique set of experiences. The team also drew heavily from recommendations derived from empirical research in developmental psychology and early childhood education.

The Astronomical Society of the Pacific (ASP) received five years of National Science Foundation (NSF) funding in 2012 to carry out this project. Our research focused on the following question: *if and how can engagement in astronomy experiences develop age appropriate science thinking skills in preschoolers and very young children?* Titled, *My Sky Tonight: Early Childhood Pathways to Astronomy (MST)*, very young children and their families engaged in age appropriate astronomy experiences in settings that included science centers, planetariums, libraries, and other informal learning environments. In addition, we studied the impact of combining imaginative narrative with hands-on experiences. One of the toolkit activities, *Bear's Shadow*, incorporates the storybook *Moonbears' Shadow* by Frank Asch and engages children in investigating shadows. With supplemental funding, we field tested, revised, and studied a new storybook, *Breakfast Moon* by Meg Gower, which introduces children to the pattern of lunar phases, as well as the Moon's position in the daytime sky.

The research and development of astronomy activities for young children involved the following steps:

- An initial meeting of the MST project team and advisory board – consisting of renowned experts in informal learning, astronomy education, early childhood development, informal education research, and program evaluation – assisted in the initial development of astronomy activities, research instruments, and research protocols.
- A pilot kit of astronomy experiences for young children was developed and disseminated to 40 museums for evaluation and field-testing in two rounds. Revisions were made based on each round of evaluation result, with several rounds of iterative testing at partner museums between versions of the toolkit.
- Along with the pilot activities and resources, educators at the testing sites received over 18 hours of on-line professional development (both synchronous and asynchronous) focused on helping them develop the knowledge and skills needed to successfully facilitate these activities with preschool age children.

Figure 1: MST project team and expert advisors discuss the initial set of astronomy activities for very young children.

Through this iterative process of development and testing, the project resulted in a final astronomy kit that includes: 9 field tested astronomy activities, 2 children's songs supporting the astronomy content, and 12 training videos for educators focused on how to facilitate the activities with preschool age children.

II. EXAMPLES OF ACTIVITIES

II.1 “Hide And Seek Moon”

Figure 2: Using a tool (binoculars) to notice tiny objects pasted on a poster of the Moon.

A large photograph of the Moon is hung on a wall. Small images of familiar objects are placed on the photograph of the Moon, representing items an astronaut has lost and apparently left behind, including an ice cream cone, a teddy bear, a boot, a pair of gloves, and a bucket. When the children stand 10-12 feet (3-3.5 meters) from the photograph, they can tell there are small objects on the lunar image, but they are too far away to identify what they are (**Figure 2**). When given 2X binoculars to use, designed especially for their small faces and tiny hands, children find they can more easily identify the objects and help the astronaut find the things they misplaced. While observing the Moon through binoculars, children are encouraged to describe what they notice and compare what they see using the tool versus with their unaided eyes *(“How does it look different when you use the binoculars?”*). The very youngest children might not be able to articulate differences in appearance, but older children might use terms like “bigger” or “closer.” As an extension, children are given a photograph of the Moon and a marker and encouraged to mark the location of the astronaut’s lost things. Children practice a number of science practices through this activity, including ***using tools***, ***noticing***, ***collecting data,*** and ***making comparisons***.

II.2 “Bear’s Shadow”

Figure 3: Exploring how light creates shadows by noticing and comparing.

Children listen to the Frank Asch story, *Moonbear’s Shadow,* and recreate scenes from this picture book using a Bear figurine, felt landscape, model of a tree, little felt fish, and a flashlight (to represent the Sun). In the story, Bear tries to lose his shadow after discovering it scares away the fish he wants to catch. He tries out different ideas, but his shadow always reappears. Illustrations in the book show the Sun’s apparent motion across the sky, as well as the changing size, shape, and position of Bear’s shadow through the day. Facilitators of this activity read *Moonbear’s Shadow* and ask questions designed to focus attention on the position of the Sun and the direction of Bear’s shadow in the illustrations. By asking questions about the illustrations, facilitators encourage children to engage in a fundamental science practice – ***noticing***. The story is followed by an interactive, hands-on experiment where children are given the models, felt landscape, and a flashlight (**Figure 3**). Using “challenge cards” as starting points, children are asked to recreate scenes from the story and make Bear’s shadow change in length and direction, modeling the way that the Sun casts shadows of objects (e.g. “*Try to make Bear’s shadow in front of him*”). This inquiry-rich activity provides opportunities for children to use what they notice to engage in other science practices: ***modeling***, ***making and comparing observations***, and ***using evidence*** to ***make claims*** about the shadow’s appearance.

II.3 “Moon Phase Matching”

Figure 4: Using the science skill of “noticing” to compare features (younger children) and discover patterns (older

In this activity, children learn features are important to pay attention to when observing the Moon. Children match pictures of the Moon printed on cards with sequential photographs of the Moon’s phases printed on a large banner (**Figure 4**). The Moon image cards are each labeled, so children can use the words as clues to help them, which also helps develop their literacy skills. Through the process of matching the cards to the correct photos, children are encouraged to notice patterns, ask questions, and share past experiences of looking at the Moon. The conceptual goals of the activity are to help children begin to comprehend that the Moon appears to change shape, or have different phases and there is a pattern to how the shape of the Moon’s appearance changes over time. Children also get practice in using scientific words for the Moon’s phases (crescent, full, quarter, etc.). A number of important science practices are introduced to children in this activity, including ***noticing***, ***comparing,*** and for older children, ***identifying patterns***. Recently, we augmented this activity with a new children's storybook, *Breakfast Moon*, which follows a family at breakfast as they observe the Moon's phase over several mornings, comparing the Moon's shape to the various foods they eat (e.g. banana's, partially eaten pancakes, etc.). Adding imaginative narrative provides children with examples of activities they can try and more opportunities to notice and compare. Because the family in the story is African American, the book also makes the activity as a whole more inclusive, promoting the engagement of children often underserved and underrepresented in science.

III. YOUNG CHILDREN AS SCIENTISTS

The ASP embarked on a very ambitious project six years ago that experts and colleagues in astronomy education were skeptical about. We sought to answer the question, "if and how can engagement in astronomy experiences develop age appropriate science thinking skills in preschoolers and very young children?" Through a research and development project designed to bring astronomy experiences for preschool aged children to informal venues, we discovered very young children are innately curious about the sky and the objects in it and can engage meaningfully in astronomy activities. Moreover, young children are capable of engaging in science practices, especially when provided with engaging activities designed specifically for their capabilities combined with developmentally appropriate facilitation.

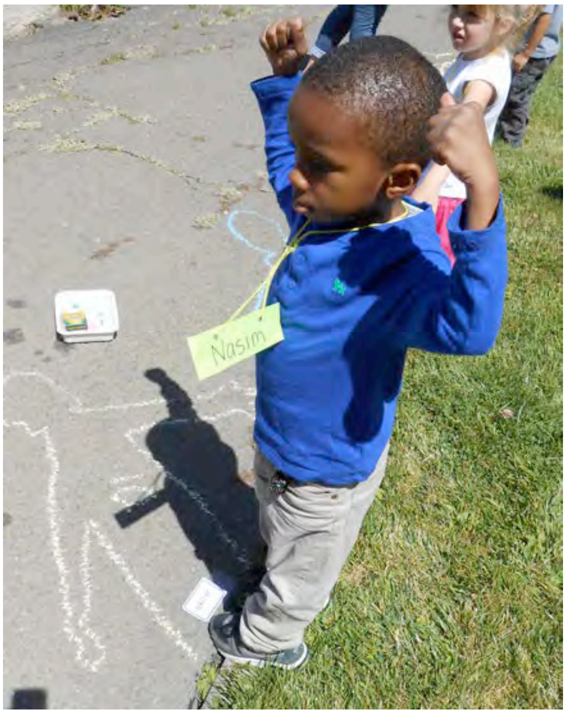

Figure 5: Children need practice noticing *salient* things; here that the direction and length of a shadow has changed over time.

But what does it mean for a very young child to be engaged in a "science practice?" We use science practices when we investigate the natural world, and in astronomy, this might include watching the motion of the sky, the changing length of a shadow, or the Moon's waxing and waning phases. But unlike sciences where you can "try things" and manipulate the world to see what happens, astronomy relies on observation, or more specifically, on your ability to ***notice***. Virtually all the activities developed by MST give young children opportunities to notice.

Resources and videos accompanying activities show facilitators how to ask the kinds of age appropriate questions that not only encourage noticing, but also help children notice the *salient* things to pay attention to; not everything you notice is important (**Figure 5**). The ability to pay attention to relevant things is critical in science; it is the foundational ability needed to compare, contrast, identify patterns, ask questions, and create evidence-based explanations (NRC, 2010). In MST activities, we went beyond helping children notice and encouraged them to engage in these practices as well – always in developmentally appropriate ways. Other science practices embodied in MST activities include using the tools of science (e.g. child-friendly binoculars to magnify distant objects) and creating representations and using models (e.g. through their drawings, things they construct, etc.).

IV. RESULTS FROM *MY SKY TONIGHT*

My Sky Tonight is currently at the end of its last year and research teams are completing their analyses. Additional information about the project, including links to research papers, educator resources, videos, and activities can be found at the *My Sky Tonight* website, https://www.astrosociety.org/education/early-learners-2/.

The following are a few findings relevant to educators in science museums and planetariums:

- **Informal educators can leverage the significant interest in astronomy that young children innately seem to possess**. Young children appear to be deeply interested in and curious about the sky. In a diary study in which 67 families with 3- to 5-year-old children were asked to record their conversations about nature over a period of two weeks, astronomy-related conversations were the third most popular topic (15% of conversations – on par with weather-related conversations). The only topics more popular were animals (32%) and plants (18%). 69% of families engaged in at least one astronomy-related conversation during the two-week period. 61% of astronomy-related conversations were initiated by children (Callanan, Solis, Castañeda, & Jipson, 2018).

- **Informal educators should encourage young children to create their own representations and make models.** MST researchers found that age-appropriate modeling encourages children's engagement in other practices of science. For example, in *Hide and Seek Moon*, children make "X's" on a diagram of the Moon, indicating where they spotted the astronaut's missing objects using binoculars. In the *Moon Phase Mapping* activity, children are encouraged to use their fingers to “draw” the shape of the lunar phases in a layer of salt sprinkled on black paper. Children’s use of representation and models supported the use of other practices, such as pattern recognition or creating evidence-based explanations.

- **Look for and encourage children to use gestures.** Very young children, especially those whose verbal skills are still in development, often use gestures to both develop their ideas and communicate explanations. Gesturing allows children to go beyond what they might otherwise be able to express verbally, externalizing aspects of developing knowledge. For example, children may point or use their hands to indicate size or distance (Plummer and Ricketts, 2018).

ACKNOWLEDGMENTS

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The Platform-Agnostic Planetarium

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BIOGRAPHIES

Mike Smail is the Theaters Manager at Chicago's Adler Planetarium. Over the last 20+ years, he has been involved at every level of planetarium production, maintenance and operation at four planetaria across the United States.

ABSTRACT

Historically, planetarium identities have been inexorably linked to their projection system's manufacturer. For better or worse, this has a noticeable effect on our ability to reach our audiences. Now, it is getting easier and more straightforward to install multiple planetarium platforms on a single computer system. Learn about challenges, successes, and ways you can make your planetarium platform agnostic.

I. SECTION 1

Historically, our instrumentation, what you have in your theater, what I have in my theater, that's what we use to create our environment. Your hardware was the planetarium. It was your projection system, it was your real-time system. You may have had a Zeiss, or a Cosmodyssee, or a Goto, but that's what you had, that's what made your environment. And in addition to creating your planetarium environment inside your theater,

Adler Planetarium's Sky Theater, circa 1930.

it sometimes extended outside your walls. I mean, how many Zeiss planetaria have you seen? How many Starlabs? Or even how many Space Transit Planetaria? Well, speaking of history, in the Adler's first 80 years we had two Zeiss projectors. That's what we had, that's what we used. In 2010, we took it all down to the walls. We embarked on, Extreme Makeover: Planetarium Edition. This is in our historic Sky Theater with our 23m dome, what you see under the external architectural dome when you approach from outside. We emptied the room to move forward with the new Sky Theater. And one of the overarching design elements and design considerations was flexibility. We're a big dome, we're in a big city, and we wanted to do a lot of big things in this space. And that doesn't just mean, flexibility in the facility itself, for example, with our removable seats. But also, flexibility in technology.

Because you always have to be looking forward. There's always new stuff coming down the road. More and more data, more and more abilities and features, and we wanted to equip ourselves to handle as much as we possibly could. It was the, highest-resolution planetarium in the world, 8K by 8K produced by 20 projectors, in 2011 when the theater re-opened. But, the big thing was not just the visual environment but also wanting to future-proof options related to the technology. Now, the interesting thing about this, like I said, we wanted to be able to respond and take advantage of new platforms, so when the theater was put in, we had Uniview, and 7th Sense for media playback. But, we wanted to add more. So we installed WorldWide Telescope. We installed Digital Sky. We installed Open Space. Quick show of hands, how many of you would install five planetarium software platforms in your theater? Ok, more than I thought, because it sounds kinda crazy, right?

In addition to flexibility, another major concern of ours is reliability. We operate 363 days a year, putting almost 600,000 people through our theaters. Think about something like software updates, you update a driver, and all of the sudden, it breaks everything and you have to roll it back. Now multiply that times five.
So, one of the really really great ideas that happened when we renovated the theater was we installed a second computer cluster. They were identical clusters when the theater opened, but when we began improving things like RAM and graphics cards, they began drifting away from each other a little bit. But the core idea is, you have your primary system, your workhorse, your system that you use for public programs that has to work. And then you have a sandbox. A separate environment that allows you to expirement with new technologies, that's what the second cluster is for. You can try those things out, you can put in beta versions of software. For example, we installed an early version of Open Space for the 2015 Breakfast with Pluto, the New Horizons flyby. We were the only planetarium in the United States (and one of two worldwide) that was able to run that OpenSpace domecast on our fulldome system, and not just as a rectangular inset video on our dome. So, the second computer cluster, great idea. I highly recommend it as a way to give yourself the ability to safely experiment.

Remember how we had 20 projectors? Eww, ehh, now this was, so, and the fun thing was that these projectors, as they started to yellow, as they started to age, we had to send them off for a three month repair process, that was very expensive, and very annoying, and, of course, when you get a projector back, it looks great! And none of the other projectors do. So it was a constant balancing act of knocking down the old projectors and eventually it was costing us a heck of a lot of money, and we realized we had to get rid of these projectors, we have to do something better, so we got some grant funding, and we were able to update our theaters. Renovate both of them, actually. So last year, we closed the Sky Theater for three weeks, put in new projectors, new lights, new computers, and again we installed a dual cluster arrangement.

Adler Planetarium's Sky Theater, circa 2017.

We had some partnerships we wanted to be able to continue with, SCISS, OpenSpace, WorldWide Telescope, and in our case, our processes and workflows required us to continue our flexible infrastructure.. Every system has its limitations, right? Your system comes with A, B, and C, and you say 'hey what about that company over there, they offer X and Y?' And if you've been in the field long enough, you know over time it's an escalating arms race and people just keep chasing upward and upward, and everybody kind of matches everybody else. And that competition is a good thing. A rising tide raises all boats.

Flexibility and reliability drive our operation. But really, if you're going to embark on something like this, you've got to know your reasons, you've gotta figure it out. Do you want that super flexibility? Are you just a really DIY type mindset? Or do you want to get in there and do as much as possible? Other stuff to keep in mind. There's a fair bit of commonality in equipment. When you look at various systems, offered by various companies in the market, you're gonna see a lot of the same things. You're gonna see a lot of the same projectors, you're gonna see a lot of the same servers. For example, one of these is an E&S cluster, and one of these is a SCISS cluster. Can you tell the difference? Some of you might. It's E&S on the left, SCISS on the right. The hardware is fairly similar, the internal hardware is fairly similar, but part of what you're really wondering is 'How'.
With these two new computer clusters, we also installed improved input switchers. We can now support four inputs to our projectors, where before we could only support two. While we currently only use two inputs, if we want to go down the road even further and put in a BlendyDome or a VJ input system or somebody else's computer cluster, those options are now open to us. So how do I make this happen? How do I go down this road?

Research, research, research. Talk to the people who put together the system you have, and the systems you're interested in. And it can be a little more difficult if you're talking about some of the more emerging technologies like the Open Spaces, but find out the requirements. Find out what's necessary. For example, when we were upgrading Open Space, we found that Open Space only ran on, at the time, a fairly high-level graphics card. Which we had fortunately just upgraded one of our clusters with, but we hadn't done to the other ones, so that was a pretty limiting factor. Likewise, as time has gone on, graphics cards, gpu performance has gotten a lot more important, things like RAM have tailed off a little bit in importance.

Figure out your reasons, find out what you want to do. I can't tell you why you might want to do this. You need to do your own research. Go back to your system vendor and ask them 'Will they support modifications to that system?' It's a good chance the answer may be no, but they might say 'Sure, try it, we'll help you back everything up so if something does go horribly wrong, you can just reset and get back to where you were.'

Again, it definitely takes a special kind of mindset. I will tell you it's not for everyone, it's not an easy thing, anyone who's looked at the WorldWide Telescope manual, the Projector Alignment section, you can back me up on that, but it can be an interesting, rewarding challenge that provides good benefit and new opportunities to your audiences if you're up to the task.

CREATING A 100-SHOW ROSTER

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Abstract: Since acquiring Spitz SciDome at BGSU, we now have more than 100 shows available in the system, including over 30 full-dome shows and about 75 classic shows, in addition to live interactive and workshop-style programs for school groups. I will describe how this extensive roster was created.

I. Introduction

The BGSU Planetarium was opened in the spring of 1984 with the construction of BGSU's Physical Sciences Laboratory Building. It was equipped with a Minolta opto-mechanical star projector and a state-of-the-art Omni-Q slide projection system from Commercial Electronics in Vancouver, Canada. These systems served it for three decades. The Planetarium is a classroom for BGSU astronomy classes and serves northwest Ohio with public shows and programs for school classes and other visiting groups.

With funding from the University, the Planetarium was renovated in 2013 and 2014 with the installation of a Spitz SciDome state-of-the-art full-dome video system. My choice of SciDome was motivated by the combination of its Starry Night sky, the ability to play back full-dome shows, the prospective ease of importing classic slide shows with the ATM-4 automation system, and the embedded Starry Night curricula and the roster of teaching vignettes created by Dr. David Bradstreet. SciDome has proved to be an excellent match to our educational university setting.

We kept the Minolta star projector and the Omni-Q control system for classic shows, though we rarely use either of them now. However, the looming presence of the Minolta in the center of the room clearly announces "planetarium" to anyone entering the room. My vision was a transition period in which all systems both old and new would be available as we gradually moved to full-dome. Everyone told me the transition period would be briefer than I expected and this indeed proved to be the case.

During our first thirty years of operation, the Planetarium built up a large roster of what are now called classic programs, about 84 of them, some produced here and others purchased. These programs included slides, soundtrack, special effects, and in some cases video. I was determined that this treasure-trove of classic shows not be lost as we moved into the full-dome era. We had also created a set of live, interactive programs, primarily for school groups ranging from pre-school to high school, as well as activities for use in our university classes.

Maintaining all the classic shows while adding many full-dome shows has allowed us to create a roster of over 100 programs available for public shows and for schools and other groups visiting on field trips. In the sections below I will describe how each type of program—live, classic, and full-dome— was incorporated into SciDome. The roster of all these programs in our Teacher's Guide and is available by contacting the author.

II. Live, interactive shows and workshops

The live interactive programs were centered on the Minolta's star field and occasionally used other props, but not pre-recorded program sections. An example would be a program showing the Sun's path across the sky in different seasons and/or from different places on Earth with students predicting rising and setting azimuths or going to them (our dome and floor are both level), depending on age. Another example would be showing various sky cycles that are used in clocks and calendars. These programs were simply adapted to use the Starry Night star field and often the additional graphics available in Starry Night. We had 13 live, interactive programs and 4 workshop-style programs, most now adapted to using Starry Night. In additional, I have also adapted the demonstrations and in-class activities in my university classes to use Starry Night.

III. Classic shows

During the three decades we operated as a classic planetarium, we built up a large roster of shows, about 84 of them, 20 produced here and 64 purchased. I did not want to lose this roster and felt that many of the shows were still viable as classic shows, even in the full-dome era, for example our own Christmas show, which is now in its 30th year and still drawing well. Rather than choosing which shows to maintain, I decided to encode nearly all of them into the SciDome system so they would remain available indefinitely, even after the slide projection and control system was no longer used.

There are many steps involved in encoding a classic show into SciDome. Since I have described this work in some detail in various GLPA Conference Proceedings, I will just summarize it here. Even before our full-dome system was funded and installed, I scanned our classic shows' 24,000 slides into digital form, did the necessary image adjustment (brightness corrections, cropping, sharpening, background removal, etc.), and solved a host of image projection and folder-organization challenges, especially with regard to blended panorama and all-sky images. In ATM-4, I created sets of virtual slide projectors whose positions on the dome corresponded to the locations of physical slide projector images. For older shows where the soundtrack came in analog form, we pulled it off our reel-to-reel tapes and digitized it. Then in ATM-4, I created slide-up and slide-down cues at appropriate places along timelines, with one timeline corresponding to each virtual slide projector. With practice, I learned to encode with the videoprojectors OFF. While this seems counterintuitive, it led to working substantially faster and with better mental focus.

Using Starry Night, I also encoded cues for all operations involving the sky. This included both static starfields and all sky motions. I also learned to normally do this, again counterintuitively, with the videoprojectors off. I also used appropriately placed "target" images to replace the need for a human operator to point out anything on the dome.

We did not have an especially robust set of special effects projectors, so I replaced sfx by images or sky motion.

Once a show, both images and sky sequences, was completely encoded, then I turned the video projectors ON and slowly played through the show, correcting errors, tweaking image positions and sizes, adding motions, and refining the visual design.

These steps together eliminated the need for a human operator (other than to press "play") and the need to use any prior equipment. Thus the encoded shows are completely self-contained in SciDome, making them trivial to play without any special set-up or prior familiarity with the show.

Our experience has been that the version of the show as imported into SciDome is superior to the original version using slides. The images are brighter if not sharper, and the soundtrack is brighter as well. With the flexibility in image placement, sizing, and motion, we have been able to enhance the visual design. So the imported version is proving to be not just nostalgic preservation, but an enhancement of the product for the future.

I began the encoding process in 2014 and it is now well along, though some shows remain to be completed. It is a labor-intensive effort, but once a show is done, it never needs further attention. In this way, nearly all of our classic shows are now encoded in SciDome and will be available into the indefinite future.

I have created a User's Guide for importing slide-rich shows into SciDome. It is available by contacting the author.

IV. Fulldome shows

While preserving our past, we also wanted to move into the future by acquiring a roster of full-dome shows. As we know, most new planetarium shows are full-dome experiences rather than classic still-image (slide) shows. We also know that the full-dome shows are expensive to purchase, typically costing thousands of dollars each rather than the few hundreds that classic shows cost. Our SciDome full-dome system came with three shows included and I purchased two more at installation time. This small set of shows got us through the first two years of public shows (2014-2015 and 2015-2016) after the renovation. Then we needed to build up a much more robust roster to carry us into the future.

While selecting shows to buy, I needed to put a budget together. First I had about $27,000 available from accumulated carryover built up during twenty years of very careful management of operating budgets. Since carryover funds were under threat from the University, there was some urgency to spend this money. Second, we had nearly $16,000 left from the renovation budget. When I suspected that this budget had expired without my being informed, I contacted the Provost and arranged for the unused funds to be returned to us for show purchase. Third, I personally contributed $20,000 to the Planetarium in mid-2016. This gift was intended to make up funds lost when an entire year's operating budget had been recently withheld from the Planetarium and the Planetarium's funding otherwise targeted. Fourth, my gift was generously matched—within a day!—by $20,000 from the Dean's and Provost's offices. These pieces together gave me a budget of about $83,000 to buy shows.

With this budget, I was able to acquire 28 more full-dome shows. Being able to buy this number of shows gave me the flexibility to choose a wide range of topics for public shows and to support a wide range of ages for school-group shows. Years of familiarity with the vendors helped me make product-wise and budget-wise choices.

The selection of full-dome shows is listed here by the vendor we purchased the show from and where applicable, the site of original production.

Included At Installation

Oasis in Space (Spitz)
Two Small Pieces of Glass (Imiloa)
IBEX (Adler)
Secret of the Cardboard Rocket (Clark)
Dawn of the Space Age (Mirage 3D)

Free

Caesar & Socrates (Colgate)
Earth to Universe (ESO)
Back to the Moon for Good (Google Lunar X-Prize)
Hot Energetic Universe (EU)

GLPA

Cosmic Colors

Milwaukee Public Museum

A Teenager's Guide to the Galaxy
Chasing the Ghost Particle
Cleopatra's Universe
The First Stargazers
Space Aliens
Did an Asteroid Really Kill the Dinosaurs

Full Dome Fx

Stars to Starfish
Trip Through Space

Geographics Imaging & Consulting

FireFall
The Alien Who Stole Christmas

Loch Ness Productions

Light Years from Andromeda (LNP)
Natural Selection (Mirage 3D)
One World, One Sky (Beijing & Adler)
Undiscovered Worlds (Boston Hayden))

Audiovisual Imagineering

Black Holes (Clark) updated
Exploding Universe (Clark)
Our Place in Space (Sudekum)
Rusty Rocket (Sudekum)
We Are Stars (NSC)
We Choose Space (Houston)

Spitz

Edge of Darkness (E&S)
Life Under the Arctic Sky (Mirage 3D)
Stars of the Pharaohs (E&S)
Tales of Maya Skies (Chabot)

Upcoming Purchases

Defying Gravity (Milwaukee)
The Cosmic Recipe (Milwaukee)
Sky Wars (Milwaukee)
Solar System Buzz (Milwaukee)
Seeing! (Mirage 3D & Koenig)

V. Current roster

With over thirty full-dome shows in hand, dozens of classic shows encoded, and a variety of live interactive school programs and workshop-style programs, we now have a roster of over 125 programs in our system. This roster provides a wide range of resources for our public and school shows. Substantial additional curricular resources within the SciDome system provide further support for BGSU astronomy classes.

Though we have a perhaps enviable roster of shows, it is important to continue building it. We have purchased nearly the entire set of classic shows available from GLPA and are gradually adding them to the system as time permits. The purchase of more full-dome shows is a less certain prospect due to recent deep slashes (nearly 40%) to our operating budget on the premise that we were overfunded, even though this budget had barely changed since the mid-1980s.

In mapping out the public show schedule for the next couple years, I am running a mixture of full-dome and classic shows. In fall 2017, we ran the full-dome shows *Tales of Maya Skies*, *Stars of the Pharaohs*, and *The Alien who Stole Christmas*, along with our own classic Christmas show *Secret of the Star*. In spring 2018, we did one- and two-night runs of most of our classic shows not produced here. In spring 2019, we plan to do one-week runs of the classic shows that were produced here. With this schedule of programs, we are giving our visitors a very wide range of program topics and styles, from our past and into our future.

Appendix A: Selected pages from the BGSU Planetarium Teacher's Guide

******** LIVE PROGRAMS ********

These programs are live interactive presentations pitched to the grade level of your class. All involve student participation. The emphasis is on the sky and on demonstrations that use equipment unique to the planetarium rather than on lessons that could also be done in the regular classroom.

In order to encourage student involvement, the maximum group size for live programs is about 55 students (two classes), except for preschool through grade 1, where the maximum is about 25 students (one class).

Live programs are about one hour long, including an introduction to the planetarium and time for questions at the end.

STAR SHAPES (Preschool and kindergarten): An introduction to the planetarium and the sun and stars, using a format of storytelling, activities, and a look at the planetarium's starfield. Maximum 20 students. (30 minutes)

DAY AND NIGHT (Grade 1): An explanation of day and night. The sun's motion across the sky is shown and the concept that it moves because the earth rotates is demonstrated. Then, the current evening sky and some constellations are shown. (30 minutes)

FIRST CONSTELLATIONS (Grade 1): An introduction to constellations for first graders. (30 minutes)

DIRECTIONS (Grade 2): A demonstration of the meaning of directions: east and west as the directions of sunrise and sunset, south as the direction of the midday Sun, and north as the direction of the pole star. The seasonal variation in the Sun's sky path is demonstrated and the current evening sky is also shown. (45 minutes)

STORYBOOK SKY (Grades 2-12): The mythology and stories of a few prominent constellations. The tales of the ancient Greeks, native Americans, and many other cultures used the sky as a storyboard. A variety of these tales are told under the planetarium sky and the students also create their own constellations and stories. (45-60 minutes)

CONSTELLATIONS AND THE SKY TONIGHT (Grades 2-12): How to find and recognize constellations, using star charts, the planetarium sky, and practice in small groups. The emphasis is on learning a few constellations well so the student can find them in the real sky. Other features of the sky such as colors of stars are also shown. The short recorded show, More Than Meets the Eye, can be included as part of this program upon request. Maximum about 25 students. (45-60 minutes)

NAME THAT PLANET! (Grades 2-4): A unique tour of the whole solar system in a modified game-show format. Dozens of pictures show each planet and comparisons and contrasts among the planets. The current position of the planets in the sky and in their orbits is also shown. This program is designed to follow, not precede, the classroom unit. (60-70 minutes)

THE MOON AND MONTHS (Grades 3-6): A lesson on watching the moon, including its phases, when it is visible, how it moves across the sky, and its appearance to the eye and through binoculars. The connection between the moon and months and a short tour of the moon are also included. (45-60 minutes)

THE SUN AND SEASONS (Grades 3-6): A lesson on how the sun moves across our sky in different seasons and why there are seasons. The sun's sky path at other latitudes is also shown in order to illustrate the midnight sun and the opposite seasons of the southern hemisphere. The lesson begins with an explanation of why the Sun shines. (45-60 minutes)

WHAT TIME IS IT? (Grades 4-6): How our clocks and calendars are based on motions of the sky. Topics include the sun's motion across the daytime sky, the stars and their movement at night, the moon's phases and their connection to weeks and months, and the changing path of the Sun in different seasons. (45-60 minutes)

LIFE CYCLES OF STARS (Grades 5-12): An explanation of the life cycle of the Sun and other stars, including their birth, evolution, and death. Examples of most stages are identified in the night sky, including examples of what the Sun was like in the past and will be like in the future. In this way, the student's appreciation of the night sky is enhanced. (60 minutes)

ASTRONOMICAL COORDINATES (Grades 7-12): An explanation of the various coordinate systems and reference circles astronomers use to record and organize the motions of the stars and Sun in our sky. (45-60 minutes)

MARS WARS: PROVING THE EARTH MOVES (Grades 9-12): The question of how we can prove three things we take for granted: the Earth is round, it spins on its axis, it goes around the Sun. The program demonstrates and explains the astronomical proofs and shows that a round, moving Earth is a sophisticated concept that was not easy to prove. (45-60 minutes)

****** WORKSHOP-STYLE PROGRAMS ******

These programs are designed for small groups in a workshop/laboratory format. In each, the student keeps a quantitative record of the sky motions being demonstrated and learns the patterns by making predictions and comparing them with observations.

The maximum group size is 25 and most of these programs require 75 to 90 minutes to complete.

WATCHING THE SUN (Grades 7-12): Demonstrates the Sun's path across the sky in different seasons and as seen from different places on the earth. Before each step, the student predicts the Sun's motion, and thus over several steps learns the trends with season and latitude.

WATCHING THE MOON (Grades 7-12): Demonstrates the moon's path across the sky at different phases and seasons and when it rises and sets. Before each step, the student predicts the motion and thus over several steps learns the trends.

WATCHING THE PLANETS (Grades 8-12): Charting the movement of the planets against the backdrop of the constellations in order to understand why planets are seen in morning twilight, evening twilight, at night, or not at all.

KEPLER’S THIRD LAW (Grades 9-12): Demonstrates Kepler's law relating the period and radius of a planet's orbit. Available for either inner or outer planets.

***********   FULL-DOME SHOWS   ************

Full-dome shows surround you with video that fills the entire dome and can immerse you in distant landscapes or reveal the night sky in all its glory. Together with narration and surrounding sound the video can show you the cosmos in a way that no other medium can. These shows are preceded by a live introduction and followed by a question-and-answer period, so allow a total of about an hour.

Kid shows

ONE WORLD, ONE SKY (preschool through 1st grade): Using Sesame Street's Big Bird and Elmo, this delightful show takes our youngest visitors around the world and to the Moon. Along the way, they'll learn about the Sun, stars, constellations, and our neighbor the Moon. (27 minutes)

THE ALIEN WHO STOLE CHRISTMAS (Grades 1 and up): Can an alien really steal Christmas? Find out in this program written in rhyme that explores the winter sky and follows the hijacked Santa from planet to planet and back to Earth. (31 minutes)

OUR PLACE IN SPACE (Grades 2-3): Join Scarlett Macaw as she solves a crossword puzzle about the sky, along the way discovering the cause of day and night, secrets of the Sun, the beauty of the constellations, and exotic places in space. (32 minutes)

RUSTY ROCKET'S LAST BLAST (Grades 2-5): Rusty Rocket's last trip is a tour of the Solar System training the next generation of rocket rookies about the wonders of the planets. (34 minutes)

SECRET OF THE CARDBOARD ROCKET (Grades 1-6): An introduction to the solar system using the story of a cardboard rocket that takes two children on an adventure trip to the Sun and each planet. Includes spectacular video effects. (public show, 2015) (40 minutes)

TRIP THROUGH SPACE (Grades 5-8): A gentle instructive tour of the Universe from winter sky to planets to stars and galaxies, including eclipses & seasons. (28 minutes)

Biology and life in the Universe

STARS TO STARFISH (Grades 5 and up): The oceans are alive with life and color, revealed here with gorgeous underwater photography and videography. (20 minutes)

NATURAL SELECTION (Grades 7 and up): Join Charles Darwin on his voyage to the Galapagos where he developed the theory of evolution by natural selection. Hear Darwin explain it all and see the sights and species that led him to his discovery. Suitable for biology classes in high school and college. (39 minutes)

SPACE ALIENS (Grades 5 and up): Is there intelligent life elsewhere in the Universe? A debate examines the pros and cons to the ultimate question: Are we alone? (28 minutes)

The Earth

FIREFALL (Grades 5 and up): Throughout its history, the Earth has been hit by meteorites, comets, and asteroids. These impacts have shaped the planet we live on today and have changed the course of life on Earth. See these fiery impacts that still take place today. (34 minutes)

DID AN ASTEROID REALLY KILL THE DINOSAURS? (Grades 5 and up): What took out the dinosaurs 65 million years ago? Was it an asteroid impact? See the evidence that the dinos fell victim to an impact from space. (24 minutes)

A TEENAGER'S GUIDE TO THE GALAXY (Grades 5 and up): Inventive Milwaukee teens created this show that will take you on a dynamic journey through space and time. Discover the origins and fate of the Earth, Sun, Moon, and Universe; visit black holes; see how cosmic collisions and water have shaped our Earth. (30 minutes)

The Solar System

OASIS IN SPACE (Grades 4 and up): Earth's water makes it an oasis for life. See how our water came from space. Tour other planets where the water has boiled away or has frozen into ice. (public show, 2015) (30 minutes)

EDGE OF DARKNESS (Grades 4 and up): The New Horizons mission returned spectacular pictures of faraway Pluto in 2015 and at the same time the Dawn mission sent home spectacular images of the asteroids Ceres and Vesta. See the best of these dark and distant worlds. (public show, 2017) (25 minutes)

UNDISCOVERED WORLDS (Grades 5 and up): We have now discovered hundreds of planets around other stars and are on the verge of finding other Earths. See how astronomers search for planets and some of their most exciting finds. (public show, 2017) (32 minutes)

Light and Telescopes

TWO SMALL PIECES OF GLASS (Grades 3 and up): The invention of the telescope in the early 1600s, how astronomers have used telescopes from Galileo's day to ours, and a look ahead to giant telescopes of the future. (public show, 2014) (23 minutes)

COSMIC COLORS (Grades 3 and up): Light on Earth and from space comes in many colors. See how these many colors of light are created and what they tell us about stars and the cosmos. Learn why the sky is blue and why Mars is red. See x-rays from a black hole, see the green in a plant leaf, and go inside the human eye. (31 minutes)

CHASING THE GHOST PARTICLE (Grades 5 and up): Astronomy from the South Pole! See stunning views of the white icescape at the end of the world! Visit the IceCube observatory that is searching for the elusive neutrinos, particles from the dawn of time that hold secrets of the cosmos. (25 minutes)

IBEX (Grades 5 and up): With teenage guides, learn about the IBEX satellite that is studying the boundary between the Sun's magnetic field and the interstellar magnetic field. (29 minutes)

Stars

FROM EARTH TO THE UNIVERSE (Grades 5 and up): A spectacular tour of the Universe from Earth and planets to stars and faraway galaxies to the edge of the Universe. (32 minutes)

EXPLODING UNIVERSE (Grades 5 and up): Explosions fill the Universe, from the Big Bang that began it all, to exploding stars, to black holes, to colliding galaxies, to the great collision/explosion that created the Moon, to supervolcanoes on Earth. Witness them all shaping and re-shaping the Universe during this show. (33 minutes)

WE ARE STARS (Grades 5 and up): The atoms that make us up were made in distant stars. Follow a group of time travelers back to Big Bang when the first atoms were made. Watch as these atoms gather into stars and galaxies. See how stars made all the atoms needed for life and how these atoms found their way to Earth and into us. (35 minutes)

BLACK HOLES (Grades 5 and up): Mysterious black holes are among the most mystifying places in the Universe. Their gravity is so strong that nothing can escape, not even light. Learn all about the weird behavior of matter, space, and time in and around black holes and see how astronomers can detect them. (37 minutes)

HOT ENERGETIC UNIVERSE (Grades 9 and up): A tour of our observatories and the Universe they unveil, with emphasis on the exciting discoveries revealed by studying x-ray and gamma-ray light. Suitable for high school physics classes. (30 minutes)

Astronauts in Space

DAWN OF THE SPACE AGE (Grades 4 and up): The human exploration of space from the Moon landings of the 1960s to today's International Space Station. See the Moon landings as never before and peek at possible future missions to Mars. Includes awesome video effects. (public show, 2016) (40 minutes)

WE CHOOSE SPACE (Grades 4 and up): Guided by the astronauts themselves, visit and tour the International Space Station, see its construction, re-live the Apollo missions to the Moon, and visit future Moon colonies. (22 minutes)

BACK TO THE MOON FOR GOOD (Grades 4 and up): Learn the life story of our nearest neighbor in space and the challenge to private groups to land a rocket on the Moon, travel 500 meters, and return images and video. (public show, 2016) (25 minutes)

Culture

THE FIRST STARGAZERS (Grades 5 and up): Discover how the first stargazers around the world experienced the sky above. Watch a first stargazer create a Moon calendar 30,000 years ago. Discover how the ancients tried to understand the sky and how modern astronomy grew from their work. (24 minutes)

CLEOPATRA'S UNIVERSE (Grades 6 and up): The life and times of the brilliant exotic Queen Cleopatra. Visit her palace and the wonders of her world. See the work of brilliant astronomers in her Egypt. (25 minutes).

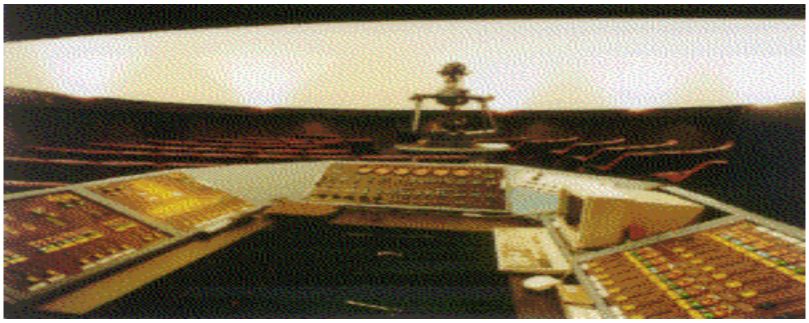
STARS OF THE PHARAOHS (Grades 6 and up): Ancient Egyptians knew the starry sky and its patterns and cycles. Learn how they brought this rich sky to Earth in their Pyramids, temples, and tombs that we can see today. (36 minutes)

TALES OF MAYA SKIES (Grades 6 and up): Discover how the mysterious Maya understood the patterns in the skies above—the Sun, the planets, the constellations—and how they tied their calendar and their earthly cities to that sky. (34 minutes)

LIFE UNDER THE ARCTIC SKY (Grades 5 and up): The Sami people of northern Scandinavia live by herding reindeer in the endless days of summer and under the aurora (northern lights) during the near-endless nights of winter. See it all in spectacular images! (41 minutes)

LIGHT YEARS FROM ANDROMEDA (Grades 8 and up): Follow a light beam as it travels for over two million years from the Andromeda Galaxy to Earth. Watch the history of Earth as the light makes its journey. (30 minutes)

****** **CLASSIC MULTIMEDIA PROGRAMS** ******



These taped programs combine narration, music, dozens or hundreds of images and other visuals, and the planetarium starfield in an instructive multimedia show. They are preceded by a live introduction and followed by a question-and-answer period.

The roster of available programs includes all of our former public shows plus several others we maintain specifically for school classes. It has been our experience that most programs designed with adults in mind also work well for children as young as grades 3 or 4. A few programs designed just for children have an upper grade limit indicated.

The maximum group size is 114, our seating capacity.

Most taped shows are about 40 minutes long, so plan a total of 60-75 minutes to allow enough time for questions.

After each program description, we have listed the running time and number of images. Programs created at BGSU are also marked BG.

For the Youngest Students

DON'T DUCK, LOOK UP! (preschool through 1st grade): Meet Dudley, a bright little duck who hatches before your eyes and begins to learn about the sky with his barnyard of animal friends. (20-30 minutes, 89 images)

LARRY, CAT IN SPACE (Grades K-2): The playful story of an inquisitive cat who takes a trip to the moon, told through a "cats-eye-view" of the moon, space travel, and living on another world. (30 minutes, 160 images)

THE LITTLE STAR THAT COULD (Grades 1-2): An introduction to stars and planets using the story of a little yellow star (the Sun) that wanders through space to meet many kinds of stars and finally discovers its own planets. (34 minutes, 147 images)

THE DAY THE EARTH TURNED THE WRONG WAY (Grades 1 and up): A story-format program on the environment in which the Earth protests environmental abuses by rotating backwards. The program shows many of these abuses and their effects and appeals to children to respect the earth. (18 minutes, 212 images, BG)

BEAR TALES (AND OTHER GRIZZLY STORIES) (Grades 2 and up). An introduction to constellations using a grandfatherly character who teaches his grandchildren the star patterns and stories about them. (33 minutes, 72 images)

The Solar System-general

NINE PLANETS AND COUNTING… (Grades 3 and up): A 21st-century tour of the Solar System, covering all the planets as well as asteroids and comets, with a special emphasis on the question of whether Pluto is or is not a planet. (public show, 2007) (42 minutes, 391 images plus video)

PLANET PATROL (Grades 3-5): An imaginative and instructive tour of the whole solar system with Investigator Sam Snork who travels around searching for a mysterious radio transmission. Includes images and video of each planet. (public show, 2000) (40 minutes, 325 images plus video)

321 BLASTOFF (Grades 1 to 4) Go with two young kids as they go on the adventure of a lifetime exploring the Sun and planets. (35 minutes, 223 images)

UNWORLDLY WEATHER (Grades 3 and up): The most spectacular weather on the Earth, other planets and moons, and the Sun, including hurricanes, tornados, thunderstorms, floods, drought, and extreme hot and cold, as well as many types of clouds, rain and snow. (public show, 1994) (44 minutes, 517 images plus video, BG)

PLANET QUEST (Grades 5 and up): The appearance of the planets in our sky, how the ancient Greeks thought all planets revolved around the earth, and an imaginary journey to each planet using space art and photography. (public show, 1986) (43 minutes, 358 images, BG)

OCEANS IN SPACE (Grades 4 and up): The oceans of Earth and other planets. Explores the Earth's oceans and their connection with life. Recreates possible ancient oceans on Mars and the probable present ocean on Jupiter's moon Europa, and visualizes possible oceans on planets around other stars. (public show, 2007) (30 minutes, 186 images plus video)

Biology and Extraterrestrial Life

LIFE BEYOND EARTH (Grades 5 and up): Explores the possibility of extraterrestrial life, the search for life-bearing planets, and the history of life on earth. (32 minutes, 375 images)

THE STELLAR THREAD (Grades 10 and up): A look at DNA, explaining its role in our lives and the origin of its atoms in the stars. Suitable for biology, chemistry, or general science classes. (46 minutes, 155 images)

THE SEABIRD SHOW (Grades 2 and up): A celebration of seabirds and their environment, including the colorful puffins which range from Alaska to Europe. Can be combined with The Day the Earth Turned The Wrong Way as a double-feature for the price of one show. (public show, 1993) (28 minutes, 363 images plus video, BG)

IN SEARCH OF PLANETS WITH LIFE (Grades 5 and up): Describes the recent discoveries of planets around other stars and considers whether these newfound planets or any of the other planets in our solar system may be suitable for life. (public show, 1998) (32 minutes, 352 images plus video)

The Solar System-individual planets

MAGELLAN: REPORT FROM VENUS (Grades 4 and up): The planet Venus as revealed by the Magellan and other spacecraft, including the spectacular surface and thick atmosphere. (29 minutes, 160 images)

TRANSIT OF VENUS (Grades 4 and up): All about the rare "transits" when Venus passes directly between the Earth and the Sun. Explains the astronomy involved and the fascinating stories of past transits. The June 2004 transit is the first since 1882. (public show, 2004) (35 minutes, 228 images plus video)

THE MARS SHOW (Grades 3 and up): A look at Mars past, present, and future: as described in science fiction, as revealed by spacecraft missions, as colonized within a century. (public show, 1988) (41 minutes, 375 images)

MARSQUEST (Grades 4 and up): Successor to the Mars Show. A new look at Mars past, present, and future: as described in science fiction, as revealed by spacecraft missions, as colonized within a century. (public show, 2002) (41 minutes, 357 images)

THE VOYAGER ENCOUNTERS (Grades 4 and up): A tour of the outer planets (Jupiter, Saturn, Uranus, and Neptune), their moons, and their rings through the eyes of the Voyager spacecraft, and a look at how the spacecraft worked. (public show, 1990) (43 minutes, 420 images)

RINGWORLD (Grades 4 and up): Saturn, its many moons, its magnificent rings, and the Cassini-Huygens spacecraft mission due to arrive at the ringed planet in 2004, go into orbit, and send a lander to the mysterious moon Titan. (public show, 2004) (35 minutes, 323 images plus video)

HALLEY: A COMET'S TALE (Grades 2 and up): The saga of Halley's Comet, its birth, its trips around the Sun, its future, and its record in history. (public show, 1985) (37 minutes, 289 images, BG)

COMETS ARE COMING! (Grades 4 and up): All about comets, including what they're like, how astronomers discover and study them, comet collisions with planets, Halley's Comet, and more. Can be combined with Cosmic Explorer for the price of one show. (public show, 1997) (34 minutes, 275 images plus video)

The Moon

FOOTSTEPS (Grades 4 and up): A program about the moon, including the moon's origin and history, early myths and stories about the moon, the Apollo manned missions to the moon, and future uses of the moon. (41 minutes, 172 images plus video)

LUNAR ODYSSEY (Grades 3 and up): An imaginary 21st century trip to the Moon that recounts the Moon's origin, tours its craters and other surface features, shows what it would be like to live on the Moon, explains the Moon's phases, and gives tips for watching the Moon in the sky. (public show, 2001) (42 minutes, 377 images plus video)

ONCE IN A BLUE MOON (Grades 2 and up): A wide-ranging program about the Moon, covering the Moon's origin and surface features, the first Moon landing by astronauts, myths about the Moon from around the world, and an explanation of the Moon's phases. (public show, 2006) (37 minutes, 295 images plus video)

The Earth

WATER WORLD (Grades 4 and up): The marvelous story of planet Earth: its birth and life history; its drifting continents, mountains ranges, and volcanoes; its oceans, ice ages, and life; and its ultimate fate. (public show, 1992) (44 minutes, 566 images, BG)

NEW WORLDS? (Grades 4 and up): To commemorate the 500th anniversary of Columbus' landfall, a story of human exploration of the Earth, including the first Americans, the ancient Greeks and Phoenicians, the Vikings, Columbus, and today's astronauts. Suitable for use with history and geography as well as astronomy classes. (public show, 1992) (49 minutes, 655 images, BG)

DINOSAUR LIGHT (Grades 5 and up): A unique trip out in space and back in time. The light we now see from stars and galaxies left them long ago, when the events we record on human history and the Earth's history were happening. The program weaves together a tour of the present-day Universe with a history of the Earth from recent events to the days of the dinosaurs. (public show, 1996) (51 minutes, 571 images plus video, BG)

AURORA! (Grades 5 and up): Examines the science and folklore of the fascinating northern lights and includes superb video of their color and changing appearance. (public show, 2001) (35 minutes, 302 images plus video)

THEY FOUND A WORLD OF ICE AND BEAUTY: POLAR EXPLORATION AT THE ENDS OF THE EARTH (Grades 5 and up): A showcase of the natural beauty and brave exploration of the Arctic and Antarctic as recorded by the eyes of modern cameras and as revealed in the adventures of early explorers. (public show, 1996) (44 minutes, 454 images plus video, BG)

COSMIC CATASTROPHES (Grades 4 and up): A look at astronomical events that may threaten life on Earth, ranging from the explosions of massive stars to the impact of giant meteorites. Also includes human threats such as damage to the ozone layer and the danger of nuclear winter. (public show, 1993) (38 minutes, 377 images plus video)

THE ENDLESS HORIZON (Grades 5 and up): The human exploration of Earth and space. Includes stone-age skywatchers, Columbus' voyage, the work of Darwin and Newton, the development of flight, and landing on the Moon. (public show, 1994) (46 minutes, 237 images plus video)

BLOWN AWAY: THE WILD WORLD OF WEATHER (Grades 3 and up): The wild and wonderful weather of planet Earth. Covers hurricanes, tornados, thunderstorms, the cause of seasons, and the effect of seasons on weather. (public show, 2008) (38 minutes, 289 images plus video)

Stars and the Universe

TO SHINE ALMOST FOREVER: THE INCREDIBLE LIVES OF STARS (Grades 4 and up): The life cycles of stars, from their birth out of interstellar gas and dust, to their lifetimes of billions of years, to their expansion to become giant stars, to their final explosions and fading out. Emphasizes how stars work, the production of chemical elements in stars, and how to see the various stages of starlife in the night sky. (public show, 1995) (43 minutes, 465 images plus video, BG)

JOURNEY TO EARTH (Grades 5 and up): A unique journey from the Milky Way to the universe at large and back to the earth to discover the place of the earth and humans in the universe. The hierarchy of structure (planets, stars, galaxies, clusters of galaxies) and vast distance scales of the universe are built up, and the creation in other stars of the elements comprising humans is revealed. One of our best programs. (public show, 1988) (38 minutes, 345 images, BG)

SPRINGTIME OF THE UNIVERSE (Grades 6 and up): The life story of the Universe and its stars, including life cycles of stars, the future of the Sun and earth, and a glimpse at the far future of the Universe. (public show, 1985) (46 minutes, 125 images plus video)

THE UNIVERSE OF DR. EINSTEIN (Grades 5 and up): A biography of Albert Einstein and a conversational approach to explain his revolutionary concepts of the Universe. (public show, 1986) (41 minutes, 258 images)

COSMIC EXPLORER (Grades 5 and up): A tour of the Universe through the eyes of artists, from the nearest planets to the farthest galaxies, and all the wonders in between. With images and music alone, the beauty of the Universe is revealed. Can be combined with Comets are Coming! for the price of one show. (public show, 1997) (13 minutes, 175 images)

DINOSAUR LIGHT (Grades 5 and up): A unique trip out in space and back in time. The light we now see from stars and galaxies left them long ago, when the events we record on human history and the Earth's history were happening. The program weaves together a tour of the present-day Universe with a history of the Earth from recent events to the days of the dinosaurs. (public show, 1996) (51 minutes, 571 images plus video, BG)

STAR STEALERS (Grades 4 and up): A cosmic "whodunit?" in which detective Sam Snork investigates the mystery of the missing stars. Along the way he learns all about the lives of the stars. (public show, 1997) (46 minutes, 339 images plus video)

ALPHABET UNIVERSE (Grades 5 and up): An astronomical sampler with a bit of everything. Twenty six topics from A to Z cover the Universe from skywatching to planets, stars, and galaxies. (public show, 1998) (48 minutes, 541 images plus video, BG)

SPACE DREAMS (Grades 3 and up): Ancient and modern dreams inspired by looking to the sky—the dreams and birth of space travel, the quest of astronomers to understand the cosmos, and the hopes of finding alien life. (public show, 2004) (35 minutes, 285 images plus video)

Astronomy in Everyday Life

WORLDS IN YOUR WALLET (Grades 5 and up): How the world's money tells the story of science. Using dozens of images of scientists on the world's money as textbook and tour guide, this interdisciplinary show covers topics in biology, math, astronomy, and physics, including electricity and magnetism, radioactivity, atoms and nuclei, gravity, and more, using an approach that combines science, history, and biography. Suitable for use with history or geography as well as astronomy or general science units. (public show, 2006) (50 minutes, 475 images, BG)

STAR-SPANGLED BANNERS (Grades 5 and up): A world-wide tour of astronomical flags and the nations, states, and cities that fly them. Dozens of flags around the world float images of the Sun, the Moon, stars and constellations, and the northern lights. This interdisciplinary program shows all of these flags, explains the celestial sights they embody, and visits the places that fly them. Suitable for use with history or geography as well as astronomy or general science units. (public show, 2003) (46 minutes, 544 images, BG)

IT'S ABOUT TIME (Grades 5 and up): The tale of astronomy's greatest effect on our everyday lives: keeping time. Our clocks and calendars record all the cycles of the sky, such as the rising and setting of the sun and stars, the phases of the moon, the passage of the seasons, and more. The program shows all of these celestial cycles and tells the story of how many early cultures based their calendars on them, thereby creating hours, days, weeks, months, years, and all the other ways we keep time today. Suitable for use with history or geography as well as astronomy or general science units. (public show, 1987) (47 minutes, 488 images, BG)

IS THIS THE END OF THE WORLD? (Grades 5 and up): An wide-ranging astronomer's look at end of the world topics. Tells the saga of the race to be first to the South Pole, commemorates the Apollo moon landings a half-century later, and explains how the moon was made. Recounts "end-of-the-world" scares caused by comets, meteor showers, and calendar changes. Looks at meteorite and asteroid impact in the recent and distant past, and forecasts the Earth's future. (public show, 1999) (48 minutes, 608 images plus video, BG)

I PAINT THE SKY (Grades 3 and up): A guide to the beautiful colors in the sky: blue daytimes, red sunsets, vibrant rainbows, shimmering auroras, icy halos, and more. (public show, 1989) (34 minutes, 476 images, BG)

CENTURIES! (Grades 4 and up): A bicentennial show that tells Ohio's history from the ancient ice ages to the modern space age. Covers Ohio's geological past, the legacy of native Americans, European settlement, Ohio's statehood, the Civil War, the Wright Brothers, and Ohio's famous astronauts. Suitable for history classes. (public show, 2003) (47 minutes, 396 images)

BAD ASTRONOMY: MYTHS & MISCONCEPTIONS (Grades 6 and up): Debunks several popular myths and misconceptions about astronomy—the Moon Hoax, UFOs and alien visitors, and astrology—all with good humor. (public show, 2009) (38 minutes, 182 images plus video)

SECRET OF THE STAR (Grades 3 and up): A program for Christmas. It shows the origin of many Christmas customs in ancient solstice festivals, retells the first Christmas story, and demonstrates several theories of the star of Bethlehem. (public show each year since 1989) (available only in December) (42 minutes, 594 images, BG)

Cultures and Astronomy

SKY STONES (Grades 4 and up): An interpretive trip to Stonehenge, the pyramids of Egypt, the temples of the Maya, and several native American sites, all part of the legacy of ancient skywatchers who recorded the movement of the sun, moon, planets, and stars in their great stone monuments. (public show, 1991) (45 minutes, 462 images, BG)

SKYWATCHERS OF AFRICA (Grades 3 and up): The legacy of African skywatchers. Includes the Pyramids and skylore of Egypt, desert traders using the stars as a roadmap across the sand, creation myths of the Dogon, prehistoric records of the Moon's phases, and more. (public show, 2005) (29 minutes, 380 images)

SPIRITS FROM THE SKY (Grades 3 and up): The star world of the Pawnee Native American Nation. How Pawnee priests watched the appearance of planets, stars, and constellations, and used them to pattern their lives and culture. Told with authentic music and the voice of a Pawnee elder. (public show, 2005) (35 minutes, 350 images)

LAND OF THE SOUTHERN CROSS (Grades 2 and up): A trip to Australia, covering the cities, land, people, animals, coasts, observatories, and the southern hemisphere skies. (public show, 1989) (45 minutes, 656 images)

SERPENTS OF THE SUN (Grades 3 and up): Ohio's prehistoric mounds and their astronomical significance. Visits Serpent Mound, Fort Ancient, and other earthen mounds which are aligned with the Sun. (public show, 1994) (41 minutes, 257 images)

ISLANDS IN THE SKY (Grades 4 and up): How the ancient Polynesians sailed vast distances of the Pacific Ocean in canoes navigating by the stars. (42 minutes, 149 images)

THE PEOPLE (Grades 3 and up): A collection of American Indian myths about the sky told using the sun, starfield, and artwork. (48 minutes, 116 images)

NAVIGATING WITH LEWIS & CLARK (Grades 5 and up): A trip with Lewis and Clark along the route they followed in exploring the American west over 200 years ago, with emphasis on how they used the sky to navigate and record their their route. (public show, 2007) (35 minutes, 299 images)

THE WRIGHT WAY TO FLY (Grades 4 and up): How the Wright Brothers developed and flew their first airplane. In an interview style, covers the principles of flight and the story behind the first flight in 1903. Suitable for history classes. (public show, 2004) (37 minutes, 150 images plus video)

HUMANITIES AND THE STARS (Grades 6 and up): A series of 11 lecture-like programs relating the mythology of ancient cultures and the night sky those cultures saw. Programs are available on the following cultures: Polynesian-Hawaiian, Mayan, American Plateau, Eskimo, Norse, British Celtic, Chinese, Hindu, Egyptian, Babylonian, and Greek. Each program describes its culture and recounts several myths. Since these programs are shorter and less elaborate than our others, you may select any two as a single show. (approximately 30 minutes, 90 images each)

Light and Telescopes

GALILEO: the power of the telescope (Grades 5 and up): Tells the story of Galileo, his pioneering discoveries with the telescope, and how the telescope has developed in the four hundred years since Galileo. (public show, 2010) (27 minutes, 223 images plus video)

HUBBLE VISION (Grades 4 and up): The latest and best discoveries of the Hubble Space Telescope, featuring dozens of Hubble's best images and what we have learned from them. (public show, 2005) (30 minutes, 238 images)

HUBBLE'S UNIVERSE (Grades 5 and up): The exciting discoveries of the Space Telescope from nearby planetary landscapes to the farthest sights we can see. Includes a description of how the telescope works. (public show, 2001) (39 minutes, 273 images plus video)

THROUGH THE EYES OF HUBBLE (Grades 5 and up): A tour of the Universe through the eyes of the Space Telescope: comet collisions with Jupiter, sites of starbirth, stellar explosions and black holes, remote galaxies, and more. Includes a description of the Telescope. (public show, 1995) (42 minutes, 250 images plus video)

FIRST LIGHT (Grades 4 and up): The story of the Space Telescope and a guide to the universe it will reveal, along with the history of telescopes. (public show, 1987) (33 minutes, 346 images)

ADVENTURES ALONG THE SPECTRUM (Grades 5-8): Light and how astronomers use it to study the universe. Professor Photon leads from the familiar realm of visible light to the invisible realm of ultraviolet, infrared, microwave, and radio energy. (42 minutes, 147 images)

Space Exploration

DESTINATION UNIVERSE (Grades 3 and up): The future of space exploration and colonization from Space Station Freedom to planetary engineering projects thousands of years in the future. (public show, 1991) (37 minutes, 365 images)

ALL SYSTEMS GO! (Grades 3 and up): The story of NASA from its inception to the development of the Space Shuttle, with emphasis on the Apollo manned missions to the moon. (public show, 1984) (43 minutes, 313 images plus video)

Watching the Sky

THE COWBOY ASTRONOMER (Grades 4 and up): The joys of watching the sky—stars, constellations, secrets of the Universe, and sky stories—all from a cowboy's point of view. (public show, 2008) (37 minutes, 113 images)

THE STARGAZER (Grades 7 and up) A curious child becomes an astronomer and learns how astronomers use light and gravity to decipher the lives of the stars. Based on a true life story. (37 minutes, 159 images plus video)

AMAZING STARGAZING (Grades 3 and up): A light-hearted and comprehensive guide to skywatching, covering constellations, the Sun, the Moon, the planets, and other sights of the night sky. (public show, 2002) (35 minutes, 196 images plus video) For older classes, the following program can also be included as part of this presentation: SAVING THE NIGHT (Grades 5 and up): A short show about the dangers of light pollution and what we can do to recover a dark and inspring night sky. (public show, 2002) (11 minutes, 68 images)

MORE THAN MEETS THE EYE (Grades 4 and up): An introduction to stargazing, showing what can be seen with the eye, binoculars, and telescopes. Available upon request as part of the live program Constellations and The Sky Tonight. (see page 3) (17 minutes, 31 images)

THE LIGHT-HEARTED ASTRONOMER (Grades 5 and up): An introduction to skywatching, both with the unaided eye and with telescopes. Upon request, a showing of the program More Than Meets the Eye can be included as part of this show. (public show, 1993) (31 minutes, 261 images)

STAR TRACKS (Grades 3 and up): A guided tour of the winter sky and a just-for-fun "space journey" combining space music and motions of the starfield. (public show, 1985) (48 minutes, 28 images, BG)

Appendix B: A User's Guide To Importing Slide-Rich Legacy Shows Into Scidome

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Preface

We acquired SciDome in summer 2014, late in my career at BGSU, after we had been building up slide and star shows for 30 years. These shows are now called legacy shows. In our renovation, we kept our Commercial Electronics Omni-Q slide automation system and our opto-mechanical Minolta star projector. Nevertheless, I wanted to import at least some of our legacy shows into SciDome to maintain them for the future.

The imported shows have proved to be visually brighter and more vibrant than their slide show versions. Thus they represent an enhancement, not preservation for its own sake. Some, depending on content, should be viable for years to come alongside the full-dome shows we are adding to our roster. When the importing process is completed sometime in 2016, we expect to retire the slide system since the imported versions of the shows are easier to run and are visually superior. We expect to keep using the Minolta, though I have used Starry Night for the sky sequences in the imported shows.

The guide below covers most of the steps we undertook at BGSU to import these legacy shows, some with elaborate visual design, into SciDome. If you are importing legacy shows into SciDome, some of sections below should be helpful, though of course everyone's circumstances and preferences are different. If you are creating new shows in ATM-4 for SciDome, some sections may still be useful. If you are working in systems other than SciDome, perhaps some of the material may be helpful anyway.

At first, the wealth of processes can seem intimidating, but with time and practice, they become easy and intuitive, and yes even fun. They are the technical steps that can help support our creative show design and our work to convey the wonders of the cosmos to our classes and audiences.

The guide has three sections:
- Slide Scanning
- Image Adjustment Before Importing into SciDome
- Encoding a Show in SciDome's ATM-4

Further information can be found in various Spitz manuals, which also contain many helpful illustrations.

SLIDE SCANNING

If your legacy show used slides, you will of course need to convert them to digital images. For small numbers, use a commercial service, but for larger quantities, do them yourself.

Choosing a scanner: An excellent slide scanner is the Pacific Images 5000, available from B&H in New York www.bhphotovideo.com and other outlets for somewhat over $1000. We used an earlier model, the Pacific Images 3650. If this new model has retained the quality of its predecessor, it will prove highly reliable and will do tens of thousands of scans without problems and will work with a Mac or a PC, connected by a USB port. One of our 3650s did 90,000 scans before problems and another did 60,000. Given the number of slides we scanned, the scanner cost amortized over the quantity of slides was about 1.5¢ per slide, a bargain indeed.

Slide trays: Avoid the straight slide tray that comes with the scanner. With cardboard or plastic mounted slides, it can jam about 1% of the time, which is too much. Instead use the Braun round slide tray that holds 100 slides, either the gray tray with 2.2 mm wide bins for cardboard or thin plastic mounts or the white one with 3.2 mm wide bins for thicker Gepe or Wess mounts as well as for thinner mounts. The white one is available at B&H for about $30. I did over 100,000 scans with these trays without a single jam. If a cardboard mounted slide is warped, you should use the individual slide loader on the scanner to avoid risk of a jam.

Scanner settings: (1) The nominal setting of 1800 dpi works well. I tried the higher 3600 dpi setting, but there was no visible improvement in the digital image when projected on the dome. (2) Turn on the ICE (Image Correction and Enhancement) dust removal at all times. Like flypaper, the emulsion side of slides will collect dust, and ICE reliably removes it from the scan; without ICE, the scan will be littered with dust, regardless of how carefully you have stored the slides or tried to clean them. ICE will miss the infrequent big dust motes on the non-emulsion side of slides; clean those manually before scanning. (3) The scanner contains other image adjustment software, but it is all post-scan. Avoid it, use the nominal settings, and instead use your favorite image adjustment software later after the scanning is done. (4) Set the jpg option to maximum quality. Storage is cheap!

Other practical scanning tips: (1) The scanner can successfully handle Ektachrome, Kodachrome, and Fujichrome slides without further adjustment. (2) If you are scanning slides in heavy mounts and filling only part of the round tray, which loads vertically, the tray may occasionally skip a place when advancing. You can avoid this problem by filling the unused slots on the tray with empty slide mounts of the same type. (3) The scanner cannot handle gray tones in black & white slides and will produce washed out images. In this case, you can project the slide on a screen and photograph it off the screen with your digital camera. (4) Always load all slides horizontally so you can re-use pre-scans on multiple trays.

Pre-scans: Before scanning, you will need to run pre-scans. In this low-res pass, the scanner will detect the areas to be scanned at high-res in the real scanning pass. Normally, pre-scanning selects the edges of the slide frame to define the desired scanning rectangle. For slides the have a lot of dark space, the software may get confused and define the rectangle poorly, but you can adjust the rectangle's edges manually before you begin the scanning pass. You do not need to have ICE turned on for doing the pre-scans, but remember to turn it back on for the real scans.

Scanning times: The scanning time depends on the speed of the computer the scanner is linked to. Expect to need about 4 hours to scan a round tray of 100 slides (plus loading and unloading time). Most of this time is being used by ICE, but it is essential. You will tell the scanner how many slides to scan, so if you have fewer than 100 slides in a tray, you will not waste time scanning empty bins. Once the tray starts scanning, you do not need to attend it again until it is done.

Naming your scans: The scanner will name each image file it creates from a scan. This name consists of a text part (default is Image, but you can change it) followed by a number. You specify the number for the first slide in the tray and the scanner increments that number by 1 for each subsequent scan.

Organizing your scans: It is essential that you carefully organize your scans for later use. My practice was to create one folder for each slide projector and load it with all the images from that projector. So all the scans from projector A1 went in order in a folder named A1, all the scans from projector A2 in a folder named A2, etc. All-sky and blended panorama images, with many different shows in the same slide tray, were bundled differently at scanning time and later sorted out to individual shows.

Then I created an Excel file for each folder, with columns listing the name of the show, the name of the projector, the file number assigned by the scanner, the tray position (in the slide projector's tray) of the corresponding slide, and the number of that slide in my slide show's visual design and list of slides. The last column had to be filled manually, but the others could be autofilled.

IMAGE ADJUSTMENT BEFORE IMPORTING INTO SCIDOME

The scanned images require several adjustments before they are ready for importing into SciDome. You will have your own favorite image adjustment programs, so will likely want to modify some of the steps below to suit your own software preferences. If you are adjusting a large number of images, try to use a program with most of the commands on one screen for efficiency. Here are the steps I did using a Mac.

Cropping, brightness and exposure adjustment, blemish removal, leveling: I did these adjustments in the Mac's Preview software, where most commands were on one pane (tools/adjust color), so it was very efficient to use. Generally, I used the exposure command to brighten an image when needed (often—because the scans were usually a bit too dark) and the brightness command to darken an image when needed (less often). Color adjustment was usually unnecessary. With practice, I could adjust about 100 scans an hour, including looking at each one individually.

The current versions of Preview do not contain the brightness command, so most of these steps (except brightness adjustment) can be done in Mac's iPhoto, using the exposure and contrast commands in the edit/adjust pane. If needed, blemish removal (retouch), leveling (straighten), and cropping (crop) can be done using those respective commands in iPhoto's edit/quick fixes pane.

When needed, brightness adjustments to darken an image can be done in Photoshop Elements; set it to the Expert level, go to the Enhance menu and select Adjust Lighting/Brightness/Contrast. You can also dim an image using the exposure command in iPhoto's edit/adjust pane but the results are usually not pleasing to my eye.

You may have other software and steps you know and prefer in place of what I have described here. Naturally, use what works and gives the best results for you.

Sharpening: I did this in Mac's iPhoto program, which has an excellent sharpening function that I set to the maximum level (100) in most cases.

(1) For cardboard-mounted slides, the scanner's focus was excellent and with sharpening, the scanned image would project well on the dome.

(2) For glass-mounted or double-chipped slides, the scanner's focus was slightly soft. If double-chipped, the scanner would focus on the second piece of film, perhaps an LPD4 or Kodalith mask or frame, since it was nearer the scanner's light than the color emulsion was. If glass-mounted, the scanner, in focusing, could detect the glass rather than the film inside. Either of these situations would yield a slightly soft focus. This softness of focus can be corrected in iPhoto by using both maximum sharpness and maximum definition in the edit/adjust pane. Applying both yields an image that will project sharply onto the dome. I tested this with a conventional video projector and again with SciDome XD after it was installed, in both cases projecting the original slide and digital image side-by-side, and in both cases the digital image was superior! I was careful to use demanding images in this test.

Offset panoramas: The slides you blended to make continuous panoramas—if you shot them straight across, skip this section. If you shot them offset, read on.

(1) panoramas: I projected our panorama level slides offset to the left to avoid shadowing from the star projector, which did not have an elevator or a pit to hide in. Thus a normal rectangle would project distorted, with the right side taller than the left and with the top side slanted. For slides that didn't have to blend, we ignored this effect. For slides that did have to blend, we developed a

procedure with our copy stand to distort the original rectangles into ones with the left side taller than the right side by an amount so the distorted rectangle would project onto dome as a normal one so it could blend properly. Now I had to undo this distorted image and give SciDome a normal rectangle. I did this undistorting in Photoshop Elements. Set Elements to the Expert level. In the image menu, select transform/distort. Place the cursor on the taller upper corner of the rectangle and drag it down until the image has become a normal rectangle.

(2) all-skies: I also projected these offset and had developed a procedure for re-photographing the projected "piece of pie" off the dome from an offset angle that distorted it into a swirl that when projected offset onto the dome would appear as an undistorted "piece of pie" and blend properly. It was too difficult to undo this distortion so I located the original undistorted "piece of pie" slides (a reason to be highly organized in storing your resources) and scanned them. For other all-sky slides that did not have to blend, but could just overlap on the dome and look okay, distorted though they might be, I scanned the slides used in the shows.

Background removal: This step removes black backgrounds from the scanned images. Once removed, the black background not only is not visible on the dome, it no longer exists as part of the image. This is critical if the image overlaps another one on the dome, for example if text is overlaid on a photo. I recommend applying it to most images, except as noted below.

This background removal is done in Photoshop Elements, which you should set to the Expert level, and which will yield an image in png format. The earlier versions of the image will have come out of the scanner in jpg format, though you may have chosen to later convert the jpgs to another format.

Do background removal with the following steps (noting that the descriptions are with reference to Photoshop Elements 13):

(1) Open the image in Photoshop Elements using the Open command in the File menu. When the image has loaded, locate the Background dialog box to the right side of the screen and double-click on it. In the New Layer dialog box that appears, click OK to make your image layer 0. Leave mode as normal and opacity at 100%. Do not click on Save or Close. Now you are ready to remove background. (If you make a typo here or at a later stage of background removal, choose Revert under the Edit menu to restore your image to background and start over.)

(2) How remove the background depends on the image:

(2a) slides that are well-framed (e.g. with a circle mask) or in which the image has a well-defined edge (e.g. the Space Shuttle) and black surroundings. Select the Quick Selection tool (lower right in the Select box) and the Magic Wand tool (lower left in the Quick Selection dialog box that opens in the lower panel). Also in the lower panel, set the Tolerance to 6 (or experiment if you want) and click Contiguous. Clicking contiguous will cause potential backgrounds within the image not to be removed; if you do want these potential backgrounds removed (as for example inside letters like O), then do not click contiguous. Now click in the black area outside the image; this selects black pixels for removal. Hit the delete key; this removes all pixels with the brightness of the pixel you clicked on +/- the tolerance you specified. The removed background is replaced with a checkerboard pattern indicating areas that have been removed.

This process may leave some jagged fuzz around the remaining image area. This is very evident and irritating during background removal, but is invisible when projected in SciDome if you are using a semi-transparent setting, as you will be for any almost any image in which you have removed background. Likewise, it will not be visible if this image crossfades with another one projected to the same place on the dome, even if they are of different sizes, unless the crossfade is very slow (many seconds). So you can ignore the fuzz.

If there are blacks in the image, but they do not come to the edge and thus do not meet the surrounding background, you can specify a higher tolerance, e.g. 25 or 50, for more complete background removal (i.e. less fuzz). If you set the tolerance too high, some of the image may be removed. Experiment!

If are blacks in the image, and they do come to the edge and meet the background, you can specify a smaller tolerance to avoid removing them as background. If even a tolerance of 0 removes blacks in the image, then you must use the marquee technique described next.

(2b) slides with irregular images (e.g. galaxies and nebulae) where image and blacks are intertwined. The magic wand method will not work well on these. Instead, select the Marquee tool (upper right in the Select box). Then in the lower panel, you choose either the rectangular or the elliptical marquee. Next, pressing the touchpad (if you are using a laptop), drag the cursor to define the area you want kept. It is best to use the minimum area that encloses the image. Then in the Select menu, choose Inverse, and hit the delete key. The background will be removed and replaced with a checkerboard pattern to show what has been removed. (If you don't choose Inverse, delete will remove the image area. Undo and make it right!) The area outside the marquee has been removed; everything inside the marquee is kept and will be part of the projected image.

In a few of these cases, the polygonal lasso tool can prove helpful. With this tool, you draw a polygon with many short straight-line segments enclosing the image area and the space outside the polygon will become background to be removed. Select the lasso tool (lower left in the Select box); then in the lasso area in the lower panel, select the polygonal lasso. To draw the polygon, click the place in the image where you want to begin the first segment, then move the cursor to the intended end of the first segment, and click again; then move the cursor to the intended end of the second segment and click; continue making segments in this way until you return to the beginning of the first segment to complete the polygon; when you click here, Elements will turn the segments into dashed lines. Then in the Select menu, choose Inverse, and hit the delete key. The background will be removed and replaced with a checkerboard pattern to show what has been removed. As with the marquee tool, the area outside the polygon has now been removed; everything inside the polygon is kept and will be part of the projected image. If you now want to remove an additional area inside the image, draw another polygon to define the area you want to remove and hit the delete key (without choosing Inverse in the Select menu) and the area inside the new polygon will be turned to background. An example of an image where the polygonal lasso might be used would be a picture of Stonehenge from the interior, where you might outline the standing stones to be kept as image and also the openings within them to be made background. You can also use the plain lasso or the magnetic lasso to free-sketch an area to be handled like the polygonal lasso area, but this can take a very steady hand.

(2c) other cases. Photoshop Elements offers other options for selecting background to be removed, but the options above can handle almost every case.

(3) Saving the background-removed image. Choose Save in the File menu. In the "Save as" dialog box that opens, set the format to png, and click Save. Next in the "png format" dialog box that opens, select no compression and no interlace, and click OK. This saves the png image in the folder you specified in the "Save as" dialog box.

(4) Closing the original image. Choose Close in the File menu. In the dialog box that appears, click on Don't Save. The original image is removed from Photoshop Elements unmodified in case you need to access it again. (You saved the modified image in the preceding step.)

Adding frames to digital images. In the classic slide-based versions of our shows, we had added frames to many of the images. These were usually circular or elliptical shapes or rectangles with rounded corners and were intended to avoid projected images that were sharp-cornered rectangles the shape of a slide frame. The frames were typically made by sandwiching a Kodalith slide of the desired frame shape with the color slide. Kodalith film is no longer available.

If you are starting with a digital image, you can add a frame to it by using the following procedure in Photoshop Elements. The steps described here apply to Photoshop Elements 13. Set Elements to the Expert level.

Open the image in Photoshop Elements. Do this by clicking on the "File" menu and selecting "Open" in the drop-down menu. Navigate to the desired image folder, select the desired image, and double-click on it to import the image into Photoshop Elements.

Then double-click on the word "Background" in the blue box to the right of the image. In the dialog box that appears, leave the mode as Normal, leave opacity at 100, and click OK. This makes the image layer 0.

Then in the row of icons above the blue box, click on the "add layer mask" icon (the circle in a rectangle). This is the first step in making a mask layer. Then click on the rounded rectangle or ellipse in the Draw box left of the image. Then in the Shape dialog area that opens below the image, click on the desired shape of the frame, for example the rounded rectangle or the ellipse. For the rounded rectangle, you can select how big the rounded corners will be by changing the Radius. Try different radii until you like what you see in the frame. For the ellipse, leave it Unconstrained to draw an ellipse or set it to Circle to draw a circle.

To draw the shape you want, put the cursor in the upper left corner of the image. Hold the mouse down and drag the cursor to the lower right corner and a dark area will appear. The image visible outside the dark area will become the frame and the dark area overlays the part of the image that will be retained.

Now select the magic wand. This is the "star on a stick" icon in the Select box to the left of the image. Next click the dark area on the image. Then click "OK" to simplify in the dialog box that appears. A crawling dashed line appears around the dark area. Next click the eye in the "Shape 1" blue box on the right; this step hides the dark shape but leaves the crawling dashed line (that shows the image area to be retained).

Now double-click on the white box next to the "Layer 0" to select the mask layer. Then go to the "Select" menu and choose "Inverse". Next click on the paint bucket in the Draw box left of the image. Be sure the mode is set to Exclusion in the Paint Bucket settings. Then click in the image area: this preserves the image and the frame is turned into a checkerboard pattern. The frame has now been deleted from the image that you will project on the dome.

Now go to the "File" menu and select "Save As". In the dialog box that appears, specify where you want the framed image to be stored. Set Format to PNG and click on Save. In the PNG dialog box that appears, leave Compression on Smallest and Interlace on None and click OK. You may have to wait a few seconds for the storage to be completed. Your framed image is now saved in the location you have specified.

Finally go to the "File" menu again and click "Close" to close the original image. In the dialog box that appears, click "Don't Save" to preserve the original image without changes.

These may seem like a long, complicated series of steps but with a little practice they can be done quickly and reliably.

Resizing: Spitz recommends resizing images so the number of pixels is a power of two in each dimension, in order to improve image quality and speed. In comparing imported shows in which images were and were not resized, I did not notice a difference in either speed or quality of the projected image, with few exceptions. Thus, we have not resized images in most shows and I do not cover it here. See the Spitz manual for directions on resizing; the internet contains descriptions of how to do batch resizing in Photoshop Elements.

Re-numbering: The image files at each step have the names and suffix numbers assigned to them by the scanner. When you are importing an image into a program on SciDome, and need to quickly locate the right image to import, it is very convenient if the number on the image file name is the same as the number the slide had in your visual design pages. Therefore it is very useful to renumber the file, replacing the number the scanner assigned with the slide's number in your visual design. This is a manual operation since it involves changing file names. The Excel files described under organizing your scans were essential to doing this step. This step is tedious, but fairly quick, and a show of 500 slides can be done in about two hours. This time is recovered after just a few imports since you know which image you are importing without laborious searching. For reinforcement, you can also see the image as you import it.

Storing folders at each step: Store every generation of adjusted images so you can go back to earlier generations if you need to. I stored complete sets of folders at the following stages: the original scans from the scanner (jpg); the scans after brightness adjustment and sharpening but before background removal (jpg); the scans after background removal (png); the scans after renumbering (png); the scans as imported into SciDome (png, identical to folders after renumbering, unless also resized). You may not have to ever go back to earlier versions, but will be glad to have them when you do!

ENCODING A SHOW IN SCIDOME's ATM-4

Drafting Chair: It's important that you be physically comfortable during the hours you will spend at the SciDome console, which is at an unusual height in order to accommodate the computers and the amplifiers. You need good seating and back support and armrests. So get a good drafting chair. The Raynor Eurotech Apollo Drafting Stool, which can be ordered on-line from most office supply companies for under $300, is an excellent investment. It has an adjustable range of heights that accommodates the height of the SciDome console. Verify the height accommodation before ordering any drafting chair and beware that most drafting chairs do not go high enough.

Setting up the show

Loading the soundtrack: The soundtrack must be in a wav format. If it is in another format, you will need to convert it. One choice of program to convert is Switch, available from NCH Software in Australia for download from their web site nch.com.au and priced at about US$30. They also have a more robust audio editing program WavePad, again available for download and priced at about US$70. You pay on-line with a credit card.

Once you have the soundtrack in wav format, load it into both Preview and Renderbox folders. I load soundtracks in folders called SOUNDTRACKS in the Preview and Renderbox slide folders on the SciDome console screen.

Loading the images: Ideally, you will have images in a set of folders, with each folder holding the images used in one physical slide projector in the legacy show you are converting. You may have these folders nested in various arrangements, but all should be bundled into a single folder that you import into SciDome. For a show named Venus, I might call this folder Venus-final. This folder should be imported into both Preview and Renderbox. It is convenient to do this from a thumb drive. Place the thumb drive in one of the USB ports on the Preview computer, and drag the folder to the Preview and Renderbox slide folders. On the Preview slide folder, I group all these slide folders in a folder called CONVERTED SHOWS.

Replacing image folders: As you develop the show in SciDome's ATM-4, you may need to modify images or add some images to your folder of images. I do this by first putting the new or modified image files in the show's folders on the external laptop I work on. Then on SciDome, I trash the existing slide folder for the show and load the new one. So long as the names of folders and images and any nesting structure of folders are identical to before, the images from the newly loaded folder will play back correctly in SciDome. Test this to be confident (I did!), but it does work. While this procedure of trashing and re-loading may sound more cumbersome than loading in a few new images, I find it is simple and quick; it avoids errors and ensures identical folders in Preview and Renderbox.

Creating the show timeline/template: Bring up ATM-4 by clicking on its icon in bottom dock on the SciDome screen. Click on New in the File menu. This will create the show template. Name the show, specify its length, and Save it. If you need to drag the show to another folder in Preview or Renderbox, now close the show and drag it, then re-open it. If you underestimate the length of the show, you can add time at the end later.

Importing the soundtrack: To import the soundtrack into your show, double-click on the Soundtrack line in the show's timeline, doing so within about the first second of the timeline. Select Load in the dialog box that appears. Choose the wav file you want. In our system, the sequence to get to the folder of wav files is ProgramFiles(x86)/SN preview/SN data/slides/soundtrack; it may be different in your system, depending how it is configured. Next insert a play command by double-clicking on the Soundtrack timeline at about 5 seconds and selecting Play in the dialog box that appears.

Times in visual design: Now play the soundtrack all the way through and on your script/visual design pages write down the time of paragraph starts and any other key times. Even though you will normally be inserting slide cues by listening to the soundtrack, it is very helpful to have these times written down. In some cases you may be using these time codes rather than the soundtrack to know when to insert a cue.

Creating timeline tracks: Corresponding to each physical slide projector in your legacy show, create a virtual slide projector in ATM-4 that points to about the same place on the dome. Each of these virtual slide projectors should have a timeline track in the ATM-4 template. To create a timeline track, select New Track/Starry Night in the File menu. In the dialog box that appears, name the track and click OK or simply return. Our slide projectors were named A1, A2, etc., so our timeline tracks were named A1, A2, etc. as well. Create as many timeline tracks as you need.

Initialization: It is desirable to clear the dome to black at the beginning of each show. There are two steps to doing this. First, insert a black scene in the Starry Night timeline track prior to the time the soundtrack begins to play. Second, in one of the timeline tracks you created, bring up an image at the 1% level in RGB, then take the image down to zero brightness, then insert a slide kill (sKill) command to kill all. These steps will clear any images or Starry Night scenes left on the dome from other work you may have been doing.

Encoding the show

Now you are ready to insert the "slide up" and "slide down" commands to bring images up and down at the desired times, in the desired places on the dome, with the desired size and brightness, and with any desired motion. Play the soundtrack by hitting the F7 key or clicking the "play icon" (green forward arrow) in the Play dialog box. When the soundtrack reaches a place where you want to insert a cue, stop the soundtrack by clicking the "stop icon" (red square) or hitting the F8 key.

Inserting a "slide up" cue: Double-click on the timeline you want to insert the cue on, at about the desired insert time. In the Command dialog box that appears with options of cues, click on the Slide cue. A slide dialog box will appear that offers many options:

Time: The time is nominally set to the time you double-clicked on the timeline. You can adjust this time. I normally set the frame number to zero; this moves the cue back part of a second so the image is actually appearing at the time you double-clicked on the timeline, which looks better than if the image is part of a second late.

Opaque/transparency selector: choose semi-transparent if your image is a png with background removed; this choice is essential if your image will be cross-faded with another image. Choose transparent if your image is a jpg (which will not have had any background removal). In no cases have I used the opaque and black opaque choices, but I recommend that when you at least once try all four choices on a variety of images to see what they do.

Shape selector: choose keystone so that SciDome will automatically shape the image so it appears correctly on the curved surface of the dome. In the infrequent cases that you want the image to fill the entire dome, choose fisheye.

Image selection: lets you choose the image in a similar way to "choose file" commands on other computers. You must tell the system what folder the image is in and specify the desired image in that folder. For the first timeline used in a show (i.e. when you are doing the very first slide cue of the entire show), you must specify the complete path to the folder the image is in. The steps on my system are ProgramFiles(x86)/SN Preview/SN data/slides to get to the folders of slides; the path may be different in your system. Next, within the slides folder, select the folder for the show you are working on; then, nested within that, the folder for the particular timeline you are on (i.e. which virtual slide projector); and finally the desired image within that folder. For the first cue on any other timeline (i.e. on a different virtual slide projector), SciDome will take you straight to the folder for the show you are working on; then you select the folder within that for the new timeline, and then the desired image within that folder. For the second and subsequent cues on any timeline, SciDome will remember to take you to the folder you used for the previous cue on that timeline, so you just have to select the image. This may sound complicated, but with just a little use it becomes easy and intuitive for however you have chosen to arrange your folders of images.

Single-click on the desired image name in the folder and the image will appear on the monitor. If it is the image you want, then double-click on its name in the folder to select it for showing. At this time, you can also see if the image is horizontal or vertical and make a mental note of the image size you will want to use (see Size section below).

RGB and opacity: set all four parameters to 100 for maximum brightness and natural color, unless you want a dimmer image or a modified color.

Fade time: 2 seconds is a good choice. To my eye, 1 second is a bit too fast, but your judgement may differ. If you want the slide to switch on abruptly, choose 0. Experiment to determine what fade time looks best to you.

Size: this specifies the horizontal dimension of your slide in degrees. The best choice will depend on the scanning history of the image (or if it was imported from another digital source or was photographed off a screen). For my system, 40 is usually a good choice for horizontal slides and 25 is a good choice for vertical slides. The best choices may be different for your system and your preferences, so experiment. The system prohibits sizes bigger than 90; if you enter a bigger size than 90, it will be treated as 90.

Position: specifies where the center of the image will appear on the dome. You will usually place an image by giving its azimuth and altitude. Altitudes open upward: 0 means the horizon and 90 means the zenith. For panorama-level images, 10 is a good choice (but see notes farther along on blended panoramas). You can choose negative altitudes if you just want to show just the top part of the slide, as parts below the horizon do not show. Azimuths open counterclockwise: 0 is in the front, 90 is on the left side as you face front, 180 is in the back, and 270 is on the right.

You must specify azimuth and altitude the first time you insert an image on a given timeline. ATM-4 will remember the values you specify and suggest them the next time you insert an image on the same timeline, so you will not need to re-enter an azimuth and altitude unless you want to make a change. For convenience, I suggest creating a table of azimuths and altitudes of each timeline (i.e. each virtual slide projector); this will ease your setting up the first "slide up" cue on each timeline, and you can always relocate images later if desired.

If you have slides that were used in a left-center-right configuration halfway up the dome (i.e. above the panorama level) in the legacy show, an altitude of 45 and azimuths (of image center) of 60, 0, and 300 (going clockwise from left) may work. When you see the images on the dome, you may need to adjust these to avoid overlaps or to improve appearance and spacing.

You can also specify the position of the image center using right ascension and declination. This is especially helpful if you want to align an image (such as a target symbol) with an astronomical object. If you then move the sky, the image will track with sky's motion and stay aligned with the star or whatever astronomical object you have placed it on. If you use a target symbol to point out astronomical objects, you can eliminate the need for a live operator to point things out, should that be your preference.

Roll: will normally be 0, but can be used to rotate the image. Roll opens counterclockwise, so 90 rotates the image 90° counterclockwise, 180 turns the image over, and 270 rotates the image 90° clockwise. The roll can be instantaneous or spread over a time you specify.

Parameters carried over: The following parameters are automatically carried over to the next use of the Slide command on the same timeline, so you do not need to re-specify them unless you want to change them: image, transparency selection, shape selection, RGB & opacity, size, position, and roll. Note that fade time is not carried over, so you need to specify it each time.

Inserting a "slide down" cue: same as inserting a "slide up" cue (i.e. a Slide cue), except that now RGB and opacity should all be changed to 0. An option here is to just set opacity to 0, but this leads to jerky crossfades, so is not the best choice. Always take a slide down using the Slide cue, not the sKill cue.

Inserting a slide kill (sKill) cue: this removes a slide from memory (i.e. from the memory being used by the show, not from the folders of slides!) and is essential to keep memory from getting clogged with image files that have already been used and are no longer needed. To insert this command, double-click on the timeline after the "slide down" cue and select sKill in the Command dialog box. In the sKill dialog box that appears, leave "just this track's slide" selected and click OK. You can adjust the time, but there is no need to. Two important notes: (1) do not use this command to dim a slide (that is, treat taking the slide down and removing it from memory as two separate operations); (2) insert this command after every time you take a slide down! The kill will apply only to the most recent slide in the current timeline.

If you do want to kill slides in all timelines, select "all slides" in the sKill dialog box. This is an easy way to get rid of all prior slides while you are editing a show and have "rewound" and started playing in the middle of the show: select "all slides", click Execute, and then click Cancel to remove the cue unless you want it to remain in the show.

Testing a cue: To perform a cue without storing it, click on Execute. If you are satisfied, click OK and the cue will be stored. If you are not satisfied, modify the cue and try again, or click Cancel. Beware that Execute only performs the cue, but does not store it; you must click OK to store the cue. If you click OK but not Execute, the cue will be stored, but it will not be performed until you are in play mode and the time bar runs past it.

Cue vs. narration timings: Since images are normally set to take a second or two to fade up, the cue should be placed about a second before you want the image to appear or crossfade. In this way, the action on the dome will appear at a time that looks natural. Of course, adjust to your own tastes.

Making motions: You can add a zoom effect by changing the image size, a slew by changing the image position, or a spin by rotating the image. To do this, insert a slide cue after the image has been brought up, change the desired parameter(s), and specify a time duration for the change to occur. Beware that if you take the slide down before the change is complete, the image will jump to the final setting before fading down.

Overlaid images: If you have two images from two different timelines up at the same time projecting to the same place on the dome (for example, text overlaid on a picture), the image brought up later will be hidden behind the image brought up earlier (unless the first image is transparent). You can solve this problem by bringing up the image you want to be in front first. Even one frame earlier is enough.

If it isn't possible to bring the front image up just a little earlier because other cues are blocking its intended place on its timeline, you can insert the "slide up" cue several seconds earlier and give it RGB values of 0 or 1 and an opacity of 0. This will import the image, but will not interfere with any image already showing at the place on the dome. Then at the desired time, use another "slide up" cue to put RGB and opacity at 100. If, for example, you are overlaying text on a picture and the text slide is png with background removed, the text will now appear over the picture as desired.

Beware that when you insert this "slide up" cue to import the image at near-zero brightness, if it is between another "slide up" and "slide down" cue for a different image, the image selection in the subsequent "slide down" cue will be changed automatically to be the same as the image selection of the cue you inserted. So check the subsequent cue and if necessary correct the image selection back to what you had originally; this will also correct any sKill command that immediately follows the "slide down" cue.

Unstitched pans and all-skies: We did not attempt to stitch images from our 12-frame panoramas or 6-frame all-skies into single panorama or all-sky images for SciDome. Rather, we imported them into SciDome as 12 or 6 separate images to be projected at the same time. If you have sets of images like this, you can proceed as follows.

All-skies: load them as jpg images (with no background removal) and in the "slide up" cue set the transparency selector to transparent, set the altitude to 45, and set the size to 60 (for the horizontal width at the base). If the front-center "piece-of-pie" straddled the south point (azimuth 0), set the azimuths of the six images to 0, 60, 120, 180, 240, and 300 (going counterclockwise). The images will probably overlap, but to the eye they will blend seamlessly on the dome in most cases. Adjust if necessary.

Pans: you can load them as jpg images and in the "slide up" cue set the transparency selector to transparent, or you can load them as png images with background removed and the transparency indicator set to semi-transparent. One or the other option will be better, depending in part on whether the images on the slides were soft-edged or hard-edged. You will have to experiment to see which looks better to you.

Set the altitude to 10. If this leaves the bottom of the image above the base of the dome, lower the altitude as needed if you want the pan to rest on the base of the dome. If your pan was a 12-frame pan, try azimuths (for the image center) of 15, 45, 75, 105, 135, 165, 195, 225, 255, 285, 315, and 345 (going counterclockwise from front-center).

Once the pan images are loaded, you will probably have to adjust them so they blend well. First adjust the altitude on all of them so the base of the image is on or below the horizon; in our system, an altitude of 8 works well for this, but it may be different in your system with your images. The reason for this adjustment is that it will hide any "sins" at the bottom of the images since they will now be at or below the horizon and thus not seen. There are three adjustments readily available to help you move the images so they blend well. One is azimuth, to move the image right or left; another is altitude, to move the image up or down; a third is roll, to rotate the image. You can also adjust the image size, but in general I do not recommend doing this. You can also adjust the image brightness to help improve blends. You can also bring the images up in different orders to take advantage of later images hiding behind earlier images where they overlap if they are in png format with background removed. In some cases, you may have to go back to the image adjustment steps and crop the image more tightly. In general, you will have to experiment some at this stage to find what works best for you. I have found that with all-skies, I did not have to experiment in this way, and infrequently might delete an image to make the scene on the dome look good.

Maximum number of simultaneous "slide up" cues: ATM-4 can handle a limited number of "slide up" cues simultaneously without the system freezing up. In my system, this limit is between two and six, depending on the complexity (pixel size) of the images. This problem is readily solved by separating the cues slightly in time, by as little as half a second. Spread-out cues often look better on the dome anyway.

The limitation is most apparent when trying to load 12-frame pans or 6-frame all-skies, and again is solved by spreading the cues out slightly in time. For all-skies, you can first load the front three images and half a second later load the back three images. Or you can bring up any one image first, then move either right or left and bring the remaining images at half-second intervals. For pans, you can also begin by bringing up any one image first, then move either right or left and bring up the remaining images at half-second intervals. Though this strategy makes it obvious to the audience that you have multiple unstitched images, it does create a visually pleasing roll-up effect. Or you could bring up the front two images first, then a half second later bring up their neighbors to the right and left, and proceed around the rest of the pan in this way. Again, it may be obvious to the audience that you have multiple unstitched images, but a visually pleasing wrap-around effect is created. There are many other possible sequences here and you can experiment to find what works best and looks best to you.

There does not appear to be any practical limit on the number of simultaneous "slide down" and sKill commands: I have had as many as twenty at identical times without problems.

Importing Starry Night favorites: The Scene command loads Starry Night favorites into your show. At the desired time, double-click on the Starry Night timeline. In the dialog box that appears, click on Scene. In the dialog box that now appears, adjust the time as desired and select the Favorite you want. The selection path will depend on where you have stored your Starry Night favorites for the show. When you have selected the Favorite you want, click OK in the dialog box.

If you also have images up at the same time as the sky is on, they will appear in front of the sky. So if the sky is moving, the stars will blink out when they go behind an image.

This guide is not a Starry Night tutorial, but there is one essential step in creating your favorites so they appear properly on the dome. In the Local View section of Starry Night's Options pane, be sure the cardinal points are turned on—always. Do this by being sure that the Labels check box is ticked. Check this box before storing any Favorite; if the Labels box is not ticked, the Favorite may look okay when you set it up, but it will load incorrectly when it is retrieved later for use in the show (or for live use in a class). If you don't want the cardinal points to be seen, make them black or very dark and faint, but they must be left on. If they are not on, Starry Night will reorient your favorite to the horizon and it will appear incorrectly on the dome.

Inserting video clips: Import the clips as you would slides and store them in both the Preview and Renderbox movies folders. The clips must be in mov format. Use the Slide cue to insert a video clip and in the dialog box, select Movie rather than Slide. Then select the clip you want from the Renderbox folder, place and size it on the dome, and set RGB and opacity to 100. For good resolution, do not make the size too big—about the average size of a slide is good. When the clip has finished playing, its screen will go black, so you do not need a "down" command as with slides.

Some topics not covered: You can also import material from Layered Earth and you can control special effects devices with ATM-4, but those topics are not covered here. This guide also does not cover the use of stitched panoramas (as from Panorama Factory) or stitched all-skies. See the Spitz materials for further information.

Fixing/editing the show

I strongly recommend that you do all the encoding steps with the projectors OFF. At first this may seem counterintuitive, but once you have determined what image sizes work for you, have internalized where given azimuths and altitudes are on the dome, and are confident in your use of the commands, you will find that it is faster to program without seeing the dome display. It took me a while to understand this, but it lets me program much faster than if I were constantly checking the dome.

I also recommend that in general you complete programming all the image cues before importing the Starry Night favorites. Once you have set up your favorites in Starry Night and verified on the dome that they do what you expect, then you may be able to import them into your program with the projectors OFF, using just the soundtrack and its times.

When you have all the image cues and Starry Night favorites cues encoded in your program, now you are ready to see the show on the dome. Turn the projectors ON and go through the show, stopping as often as needed to fix errors and make adjustments to improve the visual design. Here you can adjust image positions as desired by small or sometimes large amounts or change timings as desired (by dragging the cue along the timeline or by changing the time in the Slide command dialog box). You can also add or modify motions as desired. You will make adjustments to any prior visual design you had, even if it was completely error-free in the legacy slide show; SciDome has more capability and you will take advantage of it.

My experience is that in entering cues from the visual design of an error-free legacy show, with the slide folders designed so that the slides are in the same order they will appear on the dome (i.e. for maximum efficiency in locating the images to load), I can encode about 30-40 images an hour, including both "slide up" and "slide down" cues. In planning my work time, I assume 30. This is substantially slower than recoding cues with physical faders for brightness and push buttons for slide advance in real-time programming systems, but the prospect of easier editing makes up for it.

The time it then takes to go through the encoded show, clean up errors, and make adjustments depends of course on the complexity of the show and the number of changes you make, but I can typically move through about 50-75 images in an hour, a little faster in some cases, and much slower in especially complex parts. This is not a fast process, but it is where you make sure you have it right and are constantly "rewinding" and verifying parts where you have made adjustments until you are satisfied.

When you have completed this pass, go back and play the show through again to make any further changes or to correct errors in your editing. If you were really careful in your first editing pass, this second pass will be quick and then you are done!

Backing up your show

In addition to the Acronis back-up system provided by Spitz, I also back up my shows on a 125 Gb SanDisk thumb drive, where for each show I store the folder of images, the cue file, the folder of favorites, and the soundtrack. This provides an extra layer of security even if the SciDome computer were to fail catastrophically. I expect that this is only a teddy bear I will never have to use, but I recommend that you back up your work in a similar or superior way.

Learning

As I write this, I have had SciDome for just less than a year, have encoded 34 legacy shows, and have navigated daunting logistical challenges over the past several years in scanning in 23,000 show slides (and 148,000 other slides) and organizing and adjusting all the images. With each show import, I am still learning more. You will too!

THANKS

to three former students who contributed to the work described here:

Ted Schultz (1980s)—now at Marathon—for developing the photographic techniques for handling offset panoramas

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&

to Bowling Green State University for funding our installation of SciDome.

Data to Dome

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ABSTRACT

The Data to Dome Initiative is a broad effort to help the planetarium community capitalize on the big data era, with the goal of increasing the potential for scientific communication and storytelling in the planetarium. This presentation will summarize the progress of this initiative in the two years since the last IPS conference.

INTRODUCTION

The mission of the IPS Science and Data Visualization Task Force is to streamline the process of going from data to dome, increasing the potential for scientific communication and storytelling in the planetarium. 'Data to Dome' is a term which describes the broad efforts of the community to realize this mission. The efforts of the task force have been divided into several initiatives. This paper will examine the progress in each of those initiatives.

PREPARING PLANETARIA FOR THE BIG DATA STREAMS THAT WILL COME FROM NEXT GENERATION TELESCOPES, SATELLITES, EXPERIMENTS AND COMPUTATIONAL SIMULATIONS.

Next generation astrophysics projects will collect unprecedented amounts of data. The Large Synoptic Survey Telescope will collect 30 terabytes of data per night. The Square Kilometer Array will produce 160 terabytes of data every second! Processing, reducing, and making meaning of these data streams is incredibly challenging. On the visualization side, new techniques are needed to deal with these kinds of data volumes. For example, the majority of software systems currently in use in the planetarium work by loading a catalog of known astrophysical objects in to the graphics card's memory. The number of stars, asteroids, and galaxies with known 3D positions has been small enough (millions) that it can easily be loaded onto modern graphics hardware. A digital planetarium system with modern graphics hardware can visualize approximately 50-100 million stars in this manner. In the Summer of 2018 the second data release of the GAIA catalog (Gaia Collaboration 2018) included 1.7 billion stars. However, it is still possible to visualize that many stars in realtime. In fact that has been accomplished both in the Gaia Sky software (Sagristà et. al 2018), and in OpenSpace (Bock et. al 2017) which runs in a planetarium. The techniques to do this involve subdividing 3D space, and only loading the stars in the regions of space that are visible at a given moment (Alsegård 2018). Using this approach the full Gaia DR2 catalog can be visualized in realtime. Other types of data, such as volumetric or time varying, will similarly require sophisticated treatments as data volumes increase.

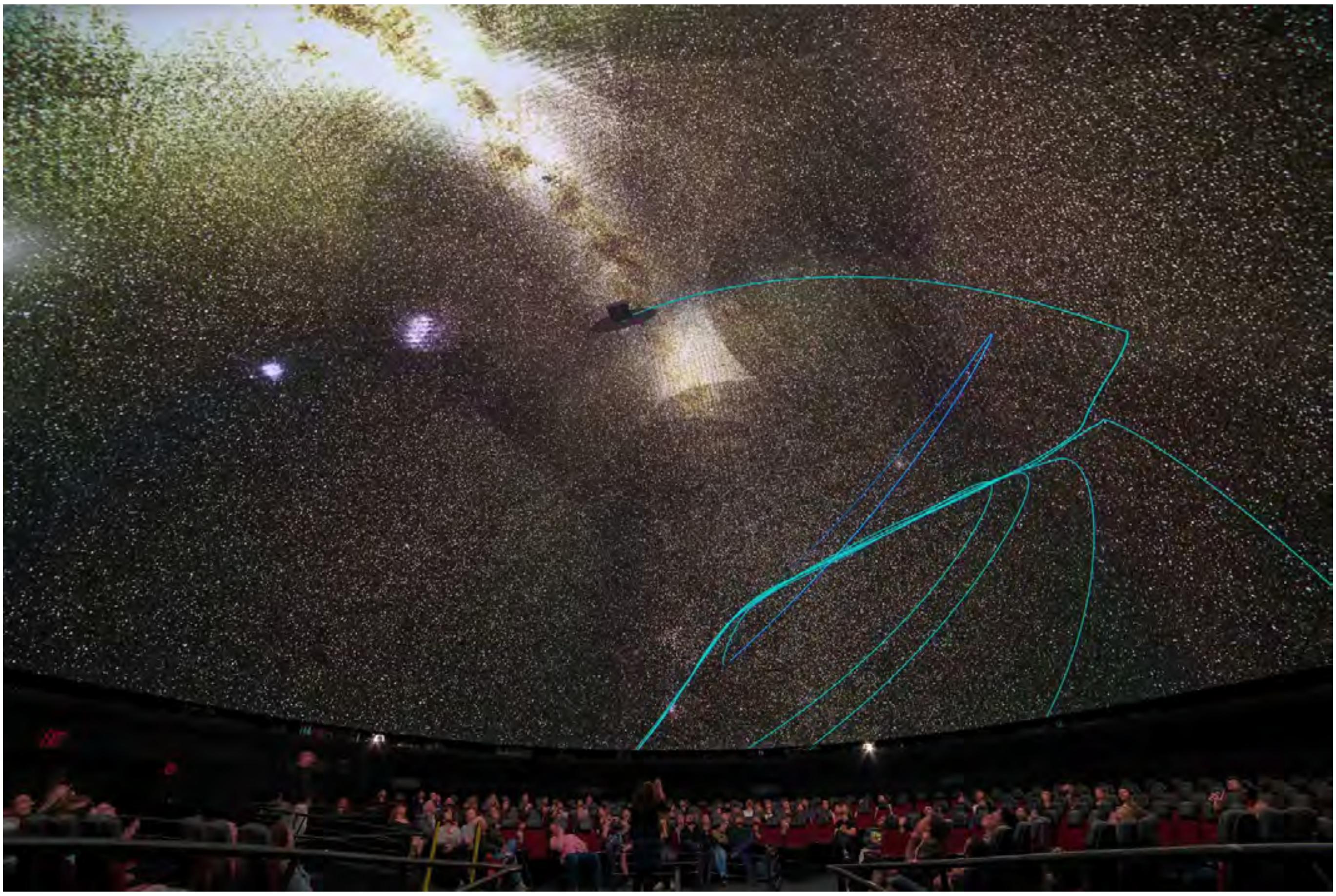

Figure 1 – 900 Million Gaia stars visualized in realtime on New York's Hayden Planetarium using OpenSpace. Photo by Matt Stanley

CREATING PROFESSIONAL DEVELOPMENT OPPORTUNITIES AIMED AT DEVELOPING MORE "DATA SAVVY" PLANETARIANS.

It is not enough that our software is capable of handling modern datasets, planetarians need to be able to as well. For this reason professional development is perhaps the most important aspect of the Data to Dome initiative. A modern planetarian requires the skills of a data scientist. The Science and Data Visualization Task Force has created a series of tutorials showing planetarians how to acquire, process and visualize various types of astronomical datasets. These tutorials make use of python and Jupyter notebooks, tools that are becoming the 'de facto' standards in the astronomical community. Having planetarians use the same tools and techniques as astronomers is a key step in streamlining the process of going from data to dome. These tutorials and other assets are available here (https://github.com/IPSScienceVisualization).

The task force has also hosted a number of Data to Dome workshops. The largest of these was the 2017 NAOJ/IPS Data to Dome workshop in Tokyo. This workshop featured not only talks and tutorials, but also a 'hack sessions' where participants got a chance to apply some of the skills that were being taught in the workshop.

Another aspect of professional development is preparing planetarians to interpret contemporary data-rich scientific stories. To that end, the task force has collaborated with LIPS (the Live Interactive Planetarium Symposium) to offer special LIPS/Data to Dome workshops at their 2017 and 2018 conferences. The 2017 session focused on the live presentation of data-rich science topics while the 2018 workshop explored ways we could make the exploration of data more interactive.

Figure 2 – The 'Hack Session during the 2017 IPS/NOAJ Data to Dome Workshop. Photo by Shoichi Itoh

CONNECTING DATA SUPPLIERS, WITH VENDORS AND PLANETARIUM END-USERS

The data2dome standard (Christensen et. al 2016) is a way for content producers to directly stream new content into the planetarium. As soon as content is made available, it will appear ready to download on the planetarium operator's console. For example, on the same day as the press release of the star S2 passing by the black hole at the center of the Galaxy, planetarians could show a fulldome video describing the significance of that event as a test of general relativity. And they could do so simply, just with a couple of clicks. The community that is supporting the data2dome standard is growing, and includes most of the major software vendors. We are working to expand the variety of content that can be streamed through this standard as well.

ENCOURAGING PLANETARIA TO MAKE THEIR FACILITIES AVAILABLE TO RESEARCHERS FROM THEIR COMMUNITIES TO USE AS A VISUALIZATION FACILITY.

The modern, networked, digital planetarium is a world-class immersive visualization facility. It is powerful tool for data exploration, one that is in many ways superior to those available to researchers working at universities or government research laboratories. For this reason, we have been encouraging planetariums to partner with researchers from their local community. The best example of suck a partnership is at the Iziko Planetarium and Digital Dome in Cape Town South Africa. Opening in May 2017, this upgraded planetarium was designed to be used as a hybrid facility, both as a traditional planetarium and as a research visualization facility. The lead researchers on this project are astronomers Michelle Cluver (University of the Western Cape, now Swinburne University) and Tom Jarrett (University of Cape Town). In addition to visualizing astronomical research, the facility has been used to by researchers in neuroscience and bioinformatics. The Iziko has also hosted public 'Data to Dome' events, where scientists get a chance to directly show off their research to the public.

Figure 3 – Tom Jarrett and Christina Hall flying through the 2MASS Galaxy Redshift Catalog

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DomePres - Live immersive presentations, from your laptop to the dome in real-time with any software.

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ABSTRACT

Producing presentations and simpler content for domes, beyond the display of a single presentation screen, comes with a steep learning curve and prohibitive work-time requirement with existing immersive content creation tools. These challenges have motivated the development of a simplistic yet powerful presentation software which can be used in any immersive environment, filling the immersive environment with content on multiple locations, yet allowing a presenter to control it from a laptop using any standard presentation tool. The presenter only needs to add markers (QR-codes) that the system will detect and decode to position and fill the display environment with content.

I. INTRODUCTION

Today, the use of a dome can be very diverse and one common usage beyond movie playback is live shows/presentations to further engage audiences through conferences and workshops in many different research, education and business areas. Most display systems require a sophisticated software to support placement of graphics, effects, playback and diverse content, often capable of running on a computer cluster. Beyond playback of prepared movies, a common use case is to create presentations that utilize the immersive display in a good way. While the use of flat presentation slides in an immersive environment, such as a dome, is still subpar to fulldome content there is still significant work for most visiting presenters to get their content onto a dome [4]. Presentation software that support immersive environments often support capturing of several video inputs through dedicated video capture cards. While this general functionality enables any person to present flat content onto a dome, or any other immersive display configuration, they do not utilize the capabilities of the display and both presenter and audience might leave with the impression that they should rather have been in a conventional lecture hall.

While it is key functionality to utilize much more space of the display surface, the presentation often needs to be prepared and altered in the sophisticated software that drives the movie playback and other aspects of the display system. A significant drawback of such softwares is that the presenter, most often, is not knowledgeable about how to prepare or modify the presentation, and that the time for content preparation is often short. The presenters may also be hesitant to handing over their material before the presentation, or at all, sometimes due to sensitivity of the material, but often because that minimizes their preparation time and flexibility to adapt with short notice. It is imperative to significantly lower the needed time and required skill level to use a dome theatre (or any other non-conventional display environment) as an immersive presentation surface. Our goal was a solution that should be non-intrusive and have a low learning threshold. It was also of importance that the presenters knowledge of the solution could be re-applied with minimal help from technical staff. The preparation time for a new immersive presentation could be achieved when coming back to the facility.

The basis of our solution is the incorporation of a marker system, QR-codes [1], in the form of standard images that are inserted into the presenters own presentation tool, such as Powerpoint of Keynote. The presentation system for the immersive display surface is then programmed to detect and decode these markers, and apply the requested operation, which in our most basic use case is placing the current slide in a specific location on the display surface. We have then moved the control of how the immersive space is used from the display software, as common in many other conventional multi-screen/space solution [2], to the actual presentation software and thus given the control to the presenter without the need to learn or work in a second piece of software.

In this work, we elaborate on our implementation, the functionality and features, the usage of this approach, and the experiences which we have gathered with its use in our own facility, where live presentations with standard presentation slides on presenters own devices are very common.

II. APPROACH

The fundamentals for this presentation tool is a software capable of rendering on the complete display surface, able to get input through a video capture card from any standard desktop/laptop computer and display that content on a plane rendered in 3D space. The attributes of the plane is not fixed, but standard parameters such that the plane can be translated, scaled or rotated is very useful, so that the presenter could position his/hers content in a location they prefer on the display.

As each frame for the input is captured and rendered, our new approach is based on that the some operations normally performed by a controller/presenter in the separate display software, for instance changing attributes of the plane, should be incorporated and controlled by the presenter in the actual presentation. There exists multiple ways of finding information inside images, but a straightforward and common approach is to have visible markers. We have chosen to use the common marker system of QR-codes [1], as there exists numerous open-source implementation of generators, detectors and decoders of these markers.

The presenter then drag-and-drops these markers (QR-codes) into their software of choice (for example Powerpoint or Keynote). Our system then captures the frames from the presenter's device during the live presentation and in real-time checks for these markers and respond to their respective action. The only limitations of which action/operation can be controlled from the presenters own software, is based on how many features we can introduce that can be controlled by a QR-code. As we wanted the key benefits of this system to be a low learning curve and short preparation time, we decided to limit the amount of operations as much as possible, based on input from previous work [3], while still making the presentation utilize much more of the display surface.

The operations can obviously vary dependent on how to best use the display surface, but our minimalistic setup is based on that there are numerous amounts of pre-defined planes (position, size and rotation parameters controlled in the display software) where the input capture from the presenters computer can be displayed. Thus the presenters only responsibility is to decide on which plane each slide/content should appear, and place the marker for that plane into the corresponding slide/position. Noticeably, the live capture from the presenter is then practically moved around from one plane to another. Thus, as soon as the presenter has decided that the next content/slide should be placed on another plane, the image/texture of the current plane is locked/frozen (i.e. showing the last frame), until the presenters decides to move the live capture back to that specific plane. For convenience, we also introduced one single marker which would hide all planes, such that the presenter can start over and enable/show desired planes, one at a time, in preferred order, when the system recognize a new marker for a certain plane.

There are, however, some aspects to consider, one being how the display system should treat the markers when detected. One significant drawback about inserting visible markers into the presentation is that the audience will also see them, which would not be desired in most cases. To remove the marker from the image when detected, we would require a static colored background of the presentation, which would also take up precious space in the presentation. Our system addresses this concern about noticeable markers by freezing the image/texture on the plane when detecting a marker with a valid operation (such that QR-codes can be used in other purposes in a presentation). The valid operation is then applied when the display system does not recognize the QR-code anymore, i.e. when the presenter has changed slide or if the image with the QR-code has disappeared as a result of a automatic operation in the presentation software (which could be a Powerpoint animation).

We created 4 planes, in suitable location for our 27-degree tilted dome with seats on differents levels, faced in more or less the same direction (slightly curved like a cinema). Thus we end up with 4 different markers, one for each plane, as well as one for hiding all, as seen in Figure 1. Figure 2 showcase an example of how slides from a Powerpoint is displayed in our dome.

Figure 1 – QR codes for operations which can be incorporated into a presentation and detected by our display software. The graph in the upper section indicates what kind of operation the presenter wants to achieve.

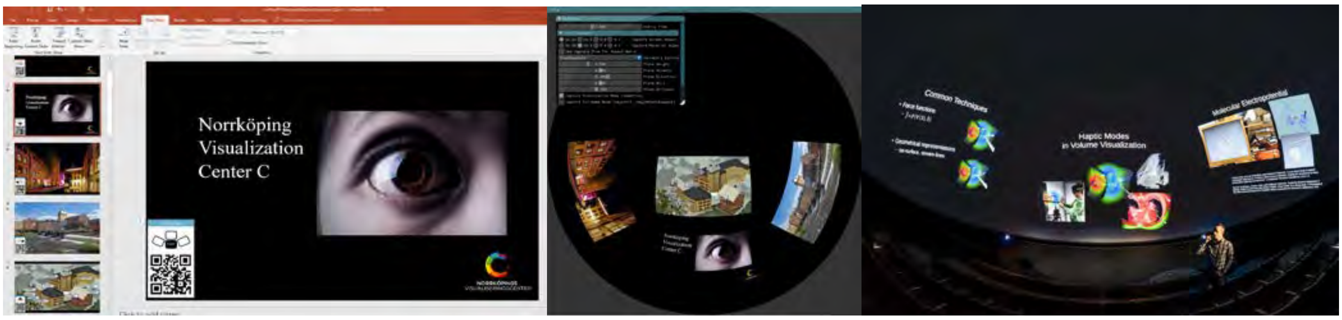

Figure 2 – Example use of the QR codes from Figure 1 in our dome application, where the Powerpoint (left) is displayed in the dome at positions shown in the fisheye/fulldome image (middle). The photo (right) is from a lecture in our dome, where the presenter is using DomePres to create a richer presentation, and all content incorporated on the dome was captured and controlled from the presenters laptop.

III. RESULTS

The tool/software we developed to use and test our approach was named ImPres (Immersive Presentation) and is open source and currently available on Github (https://github.com/c-toolbox/ImPres). While we could apply this concept and software in various environments, we have currently developed a first specific application case within this software, specific for domes, which we named DomePres (Dome Presentation). DomePres detects the markers, see Figure 1, contained in the presentation slides and a presenter can perform a presentation, as seen in Figure 2.

As DomePres is specifically created for domes, we have added additional functionality for flexible presentation. We can drag-and-drop any image in the application and place them as either background fisheye images or as flat image anywhere on the dome surface. Our software is also capable of capturing a live fisheye input (up to 4K @ 60Hz, limitation based on capture card) from a gaming machine (currently through 2 DP outputs) and displaying it in the background of the immersive presentation from the presenters connected device, which enables a real-time fulldome show during the presentation.

Our software is based on our own developed open-source toolkit SGCT (Simple Graphics Cluster Toolkit), also available on Github (https://github.com/opensgct/sgct), which supplies the features required to support any immersive display software, such as synchronizing across a cluster of image generating computers (IGs), various projections, software warping and blending based on various formats in the industry.

DomePres has been used on a number of special occasions, as for example a docent lecture as seen in Figure 2 (right). One of the current drawbacks experienced during usage has been that the presenter needs to understand that he/she needs to avoid transitions or fading effects when the QR-codes are used, as they will be visible for a while if they are faded in, until our system detects them and freezes the image. DomePres can by itself fade in/out the various planes when they are enabled/disabled. Also, you cannot reverse a slideshow and get the same outcome, so preferably the presenters would move to a slide where all planes are cleared (containing the orange QR-code) and move forward from there.

ACKNOWLEDGMENTS

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Communicating With Your Audience: Tips to Presenting Live, Interactive Programming

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BIOGRAPHY

Dayna Thompson has been Assistant Planetarium Director at Ball State University since 2012. With a M.S. in Physics she has over 10 years' experience in STEM outreach. She manages school group visits and public programing at the Brown Planetarium which sees over 22,000 guests annually.

ABSTRACT

"I want you to do something for me," is a powerful sentence when presenting to your audience. It requires them to listen and respond – to be engaged. During this session, I will present on the various ways I encourage audience participation and turn planetarium shows into a conversation instead of a lecture.

INTRODUCTION

I think we have all something in common. Each and every one of us has sat through a presentation where we have lost interest, couldn't understand what the presenter was talking about, or felt like the presentation was dragging on. For me, I had many of those feelings and thoughts while in graduate school attending the weekly physics colloquium series. The series was your basic physics colloquium. It brought in scientists from a wide range of fields who would talk about their research for about an hour. Like many other audience members, I typically was lost by slide five of their PowerPoint presentation. However there were those few times where I stayed with the presenter throughout their entire presentation. These were always the ones where I felt like they were really talking *to* their audience, and not just *at* us.

It is these presentations that inspire me to become a better public speaker. Not being a natural public speaker, I spend time practicing and studying various presentation techniques. I used to feel uncomfortable in front of an audience because I felt like there was some great standard to adhere to. The fear of making a mistake was overwhelming. I needed to just focus on presenting the way I enjoyed to get past this fear. Once I did that, most of the pressure went away and I started to have fun presenting. Being authentic and real nurtures a connection with your audience. Basically, in the words of Zefram Cochrane, "Don't try to be a great man. Just be a man and let history make its own judgements."

How can we make an impact?

Sometimes presenters can get it in their heads that they are doing the audience a favor by being there presenting. But it's the other way around. We presenters are there because of the audience. We have to make sure to consider their needs first during our presentations. When planning a presentation, you should ask: "Who is the audience and what matters to them?" Generally the audience wants to feel included above all else. In what ways can we better connect with our audience and keep them engaged?

There are many ways to do this but I will focus on what can be said, rather than shown. This comes down to creating a dialogue: a two-way conversation. I personally find it hard to be engaged in one-way conversations and lectures. When people seem to be talking to themselves, I lose interest. Therefore, I aim to have a two-way conversation with my audience. Many other planetarians do this as well. A big part of creating a dialogue is being comfortable asking your audience questions. Avoid getting caught up in the facts, figures, or data and check-in with your audience throughout the presentation. Saying the following phrases can help to maintain the dialogue when presenting: "I want you to do something for me…" or "I know that many of you may be thinking that…" or "How would it make you feel if…?" By asking the audience to simply *think* about something, a conversation is started without any verbal input from the audience. Also, these phrases can be used with an audience of any size.

Here are some examples of what these phrases could be:

- "I want you to do something for me. When you leave the dome tonight, take a look at the bright full moon in the sky and see if you can locate the spot where I said man first walked on the moon." (The location can be easily explained by looking for the upside-down bunny on the moon and noticing where its eye would be.)

- "I want you to do something for me. I'd like you to look for a backwards question mark in the stars. Take your time finding it and raise your hand when you do."
- "I know you may be thinking 'How do we know that for sure,' and I can show you how by explaining the techniques and data scientists use."
- "Given the information you learned today, what are some actions you could do or some changes you could make in your life?" or simply ask the audience in a show of hands if what they saw/heard/experienced changed the way they think about something. Or if they would change their behavior based on what they now know.
- "How would it make you feel if tomorrow we confirmed the existence of life in our universe?"
- "Imagine what Edwin Hubble felt when he discovered in 1923 that Andromeda was in fact a galaxy, forever changing our view of the universe."

When presenting to school groups, we (the audience and the presenter) are all on the same mission: To learn together as a group. We are one team. And to help keep things inclusive, I call the audience "friends." I of course have the answers and am the leader of the experience, but I am also constantly getting input from our visitors. For instance, instead of saying a fact, I sometimes ask the learners what they think the answer is. I try to use positive responses with every answer, and continue taking responses even if the correct answer has been provided. We can then usually learn the answer together by using the planetarium technology to show the answer (speeding up time to show what direction the sun rises in rather than telling them).

You can also check in with an audience by putting up a question for them on the dome. The question can be multiple choice with the answer options labeled as 1, 2, 3, or 4 instead of A, B, C, or D. This way the audience can simply hold up a number of fingers to provide their answer. This is an easy way to see what the audience knows/thinks. They can then "think-pair-share": they can talk to their neighbor about their answer, say why they think that's the correct answer, and then answer the question again with the rest of the audience. This keeps the audience engaged by feeling like they are actively contributing to the presentation. When done correctly, it makes them feel like the presentation is truly geared to them.

There is also the option to "give" the audience something to take home… more about that below.

General advice for public speaking.
The following are tips I give to our show presenters and ones that I follow myself. I gathered these tips from many different sources over the years but they are mostly inspired by TED.

1. **Know your audience** – Who is your audience and what matters to them? Consider the grade level of the audience. Recall what is learned at each grade level by going over at GLPA's Astronomy Literacy: Essential Concepts for a K-12 Curriculum, pages 5-13.
2. **Practice** – Practice speaking out loud about the subject.
3. **Listen** – Pay attention to how others discuss the subject matter. Watch examples (documentaries, etc.) and take notes.
4. **Record and watch/listen** – Notice any crutch words (e.g.: um, and, like, so…).
5. **Be honest with yourself** – There is always room for growth in your knowledge and for your presentation techniques. Admit when you do not know something and use it as a teaching moment.
6. **Carry notes** – No one is going to hold this against you. We are all human.
7. **Establish a pre-routine** – Give yourself time before each presentation to prepare. Walk around the room, check the microphone and sound levels. Run through your presentation. Try vocal exercises.
8. **Speak in an authoritative tone** – Crutch words hurt your credibility. Do not make excuses: "I didn't get much time to prepare" or, "I'm not very good at this."
9. **Be energetic but keep the pace slow** – Show the audience that it is okay to be enthusiastic about science. If you are not interested in what you are discussing, they will not be either. Remember to keep the pace slow so the audience has time to digest.

10. **Encourage questions** – Embrace questions from the audience. Always repeat the question before you answer.
11. **Try new introductions** – e.g.: Ask questions to grab attention. Tell a fact that stuns the audience. Tell a story relating to the topic.
12. **Give the audience something to take home** – Provide something specific the audience can do almost immediately.
13. **Respond to your audience –** If the audience is not responding the way you expect, change your presentation accordingly.
14. **Be comfortable with silence –** It is OK to pause and gather your thoughts once in a while.
15. **Always run a little short –** Respect your audience's time and end early. Leave time for questions and time for travel to their next event. (If you have an hour, take 50 minutes.)

More about Tip 12: Give the audience something to take home.
"Provide something specific the audience can do almost immediately after the presentation." This tip is simple but important. This does not need to be a material item. This can be an idea or a task. The task can be simple: Find the planet Venus in your night sky. It can be something more challenging: Be conscious of your water consumption and make changes to lessen your household water consumption.

You can also show them a demo that they can recreate at home. I try to create our demos with things you can find in a typical home because I think it makes science more attainable and approachable. For instance, most cell phone cameras can detect the IR light that comes from a remote control. We show this when talking about the electromagnetic spectrum and the biological limits of our eyes. This is something that amazes guests and is also something they can do when they get home on their own.

And of course this can also be something tangible like a star chart.

Communicating With Your Audience: Tips to Presenting Live, Interactive Programming

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ABSTRACT

There are many characteristics and abilities that are associated with scientists today, all of which can be learned. As planetarians, how can we go further in our presentations to help better prepare the next generation of scientists and, in turn, foster a questioning public? During this workshop, you will team up and actively explore the characteristics of a scientist. As a group, we will come up with creative activities and methods that teach planetarium learners how to be a scientist. We will also take a few minutes to hear from participants about the state of science education (formal and informal) in their home countries in order to stress the importance of promoting scientific literacy.

INTRODUCTION

Not to be confused with a **trait**, which is a *genetically* determined quality, a **characteristic** can be taught and refined over time. Certain characteristics are said to be associated with various professions. When you think of a scientist, for instance, a list of characteristics can come to mind. When asking various audiences what they think of, they sometimes answer: brainy, careful, creative, critical thinker, flexible, focused, insightful, knowledgeable, logical, objective, observant, open-minded, patient, persistent, resourceful, risk taker, skeptical, and even white lab coat.

We teach some of these characteristics to planetarium guests – whether it is apparent or not. Before discussing how, let's refine this list and focus on the following characteristics of a scientist:

Careful

Creative

Curious

Critical thinker (also: Logical, Objective, and Skeptical)

Observant

Open minded (also: Resourceful)

Persistent (also: Patient)

Risk taker

Note: We should not forget that these characteristics build off of a good foundation of knowledge. Information and facts are vital to each planetarium lesson. However, it is worth going beyond in presentations to help encourage other facets of the mind.

Tips to Fostering these Characteristics
Below are some characteristics associated with scientists and some tips to teaching them:

Careful

- Ask if there is anything else to consider before moving on to an answer/solution.
- Let learners realize on their own if they missed some important information that would have helped them with something.
- Ask learners what they could have done differently – and let them try a task/question again if possible.

Creative

- Allow time for divergent or off topic questions.
- Spend time imagining. For example: what it would be like to travel into space, live on another planet, see an alien, etc.
- Create/find new pictures in the sky or in other objects in space.
- Come up with names for exoplanets based on their characteristics.

Curious

- Encourage questions and revisit old questions when able.
- Model and promote ambition.
- Develop game-based learning exercises.
- Use diverse and unpredictable content.

Critical thinker/Logical/Objective/Skeptical

- Give reasons behind some discussion points – explain why learners are doing something.
- Talk about bias and the way emotions or motives can influence judgements.
- Present bad vs. good arguments with concrete examples.
- Create categories and classify objects.
- Ask a question and give relevant as well as irrelevant information to help them find the answer. Have learners sift through the provided information to obtain the answer.
- Ask learners to consider alternative explanations or solutions for issues.
- Ask questions that allow learners to explore ethical, moral, or public policy dilemmas.
- Provide examples of fake news/images and break them down to figure out why they are misleading or incorrect.

Observant

- Define what an observation is and point out when someone makes one.
- Emphasize that observations can be made with senses other than sight. "What do you hear?" or "How does that feel?" etc.
- Demonstrate how to measure or watch with good technique.
- Use compare and contrast exercises.
- Give learners a chance to observe or find something before showing it to them.
- Have learners list all the features they see in an object.

Open minded/Resourceful

- Be open with what the learning goals of activities are – if it's to learn how to be open minded or resourceful, explain that.
- Focus on possibilities and not constraints.
- Challenge learners to think broadly.
- Have learners draw on past experiences.
- Provide examples of scientists or people thinking "outside the box."
- Support rule-bending (Galileo).
- Teach collaboration (more minds contributing to the same task).
- Encourage interdisciplinary thinking.
- Use cross-cultural examples or stories.
- Urge learners to publicize and praise one another's accomplishments and ideas.

Persistent/Patient

- Model it. Tell a story of how you failed at something but kept trying.
- Give feedback such as: "I know you can do it if you keep at it." or "If you're really stuck, ask for help." or "Think of how good you will feel once…"
- Teach how the brain works through plasticity so learners understand that it is natural and okay if they do not succeed at something the first time.

Risk taker

- Encourage learners to take, as well as create, opportunities.
- Build learners' trust and encourage them so they will respond, speak-up, and feel like their input is valued.
- Encourage alternative solutions to problems (team work or pairs work well with this as it can sometimes be daunting for learners to give new or untested answers).
- Consider asking a question with no definite answer so learners are forced to provide original perspectives.
- Show risk taking in your own answers to issues/questions in an effort to minimize the pain of making an error.
- Let learners work and talk on their own.
- If learners are going down the wrong path, let them learn from the experience.

Sample Presentation Outline for "General Sky" Show

During planetarium programs, we often inspire future artists, writers, and various other non-STEM dreams. In addition, many of us have a mission to teach science. Although not everyone move on to get a STEM career, we know that they will benefit from these lessons as science is always around us. It's unavoidable in our day-to-day lives. Therefore, it is a good idea to start presentations with an introduction on what doing science means.

Intro

- Introduce yourself and ***science***
    - "My name is _____. I work here at the _____."
    - "When I went to school I studied __science__." OR "I am going to school and studying __science__."
        - "Raise your hand if you do science at your school."
        - "Can someone explain what it means when we say we do science?"

        - Science can be defined most simply as: "The study of the world around us in order to improve our understanding of how it works." OR "Science is a means of improving our knowledge and understanding of the universe based on the collection of observation-based evidence."
    - Model and promote ambition during introduction and throughout presentation to encourage ***curiosity*** in learners.
- Room full of ***observant*** scientists
    - "We are all scientists today in the planetarium because we are going to be making a lot of observations."
    - "Do you know what an observation is?"
        - If no one knows, define: "When you make an observation, you are taking a patient look at something and noticing things about it: facts or occurrences."
    - "We are all going to be scientists today because we are going to *observe* the world around us, ask questions based on those observations, and try to find the answers to those questions using more observations."
        - Note: A positive response is a good idea when someone makes an observation (even if it is off topic).
- Technology and ***scientific tools***
    - "Scientists need tools to do science, so we have some technology that we use as tools in the planetarium to help us. They will be able to recreate the sky and show us things that happen in real life."
        - Introduce any technology or tools you will use: star projector, computers, etc.

Planetarium guests can benefit from an introduction like this because it gives them the words that define their activities/actions. They may have also thought they didn't like science based on an incorrect view of what it entails. After discussion, they may find that they enjoy science and would even like to do more. Beyond the introduction, one can cultivate the characteristics of a scientist *throughout* the presentation. These characteristics are beneficial to all learners, not just future scientists. For example, the ability to ask questions stems from the many different characteristics a scientist has. It is important for everyone to formulate questions. This gives them the ability to better navigate various obstacles. Today, this includes the rise in fake news. Given the proper abilities, everyone can more readily sort out credible news articles from fake or biased one. Having a questioning public like this can lead to a well-informed community – a community in which we aspire to live.

"GENERAL SKY" PRESENTATION OUTLINE
EXAMPLE

	Activity/Method	**Characteristic**
1	**<u>Bring up daytime sky with Sun above horizon in the East, Moon in waning crescent phase, and clouds/birds/directions/etc. up in the sky.</u>** Ask learners to make ***observations*** out loud or to their friends next to them. Repeat as many as you can while facilitating more observations. For example: "Can you tell me if the birds are closer than the clouds? How do you know? Are the Moon/Sun are closer than the clouds?"	Observant
2		Observant

	Briefly compare and contrast the Moon and Sun based on age level of learners. (You can come back to this more later when taking “trips” to Sun/Moon.)	
3	**Sunrise vs. Sunset/directions:** **Presenter:** “Can you tell me if the Sun is rising (going up) or setting (going down)? How do you know?” **<u>Go forward in time a few hours using your technology/tools to see if the Sun is rising or setting.</u>** Explain that the Sun will always rise in the same direction each day. **Presenter:** “The Sun will always rise in the ____.” (Have learners fill the blank together out loud.)	Observant
4	**Presenter:** “I wonder why the Sun and the Moon appeared to change their location in the sky. Does anyone have any ideas?” <u>Answers may vary but often result in the following discussion:</u> **Learner:** “The Sun and the Moon appear to move across the sky because the Earth is going around the Sun and the Moon is going around the Earth.” **Presenter:** “YES, it is true that the Earth goes around or orbits the Sun, and the Moon orbits the Earth; AND how long does it take for the Earth to go all the way around the Sun?” **Learner:** “A year/~365 days.” **Presenter:** “Yes, it takes a year for the Earth to orbit the Sun. Let’s think about this carefully. Remember that we only went a few hours ahead in time and the Sun and Moon moved a large distance on the sky. Is there something else that the Earth is doing that takes less time that would cause this motion?” **Learner:** “The Earth is spinning!” **Presenter:** “Yes, the Earth is spinning or rotating as it orbits, or goes around, the Sun. How long does it take to rotate one time?” **Learner:** “A day/24 hours.” **Presenter:** “Exactly, the Earth rotates once every 24 hours and it makes it so the Sun and Moon appear to move across the sky during the day and night.	Careful/Logical
5	**<u>Speed up time and go to Sunset.</u>** After teaching what a constellation is: Instead of showing learners where constellations are, have them try to find them on their own by either explaining what one looks like or giving them a star chart. An alternative for this, especially for young learners, is to bring up constellation overlays and have them find certain animals or objects in the sky. Have them explain where they are to their friends using the directions they learned (up/down, high/low, NWSE, by the horizon, etc.).	Careful/ Persistent

6	"I wonder what it would be like to: go into space, visit another planet, see the sky from somewhere far away and name new constellations, etc." Then take a trip to somewhere in the solar system or beyond. You can also have them try and name or rename new things they see together.	Creative/Curious

Presentation Outline by Workshop Participants

During this workshop, participants worked in groups to come up with various activities specifically designed to facilitate one of the characteristics associated with a scientist (that was their creative constraint – see below). For instance, people whose show topic was "Moon Phases" had to focus on teaching students to be "careful." EM Spectrum:Creative, Intro to SS:open minded, Jupiter and Juno:Persistent, and eclipses:risk taker.

SHOW TOPIC(S): _________________ CREATIVE CONSTRAINT(S):__________________

	Activity/Method	**Characteristic**
1		
2		

Data to Dome: How do we make it live and interactive?

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ABSTRACT

The International Planetarium Society's (IPS) Data to Dome initiative is making it easier to bring cutting edge scientific data into the planetarium. This workshop will focus on the question: Once we get the data on the dome, how do we talk about it with our guests? Help us explore how to engage our audiences in discussions concerning current science, supported with data-rich visualizations. Presenters will also invite feedback from the audience on what barriers are preventing them from implementing data-driven presentations in their domes. This session is an accompaniment to a March 2017 workshop presented in association with the National Astronomical Observatory of Japan (NAOJ) and a July 2017 workshop presented at the Live, Interactive Planetarium Symposium meeting.

INTRODUCTION

Roughly 35 IPS 2018 registrants attended this Data to Dome workshop on making it live and interactive early morning on the last day of the conference. Participants in the hour-long workshop teamed up to choose datasets, to consider audience needs in making sense of data, and to develop strategies for helping interact with data. In this write-up, we will summarize the workshop materials and collected responses from participants.

I. WE ARE COMMUNICATORS OF INFORMATION

To start the workshop, we reminded participants that as presenters, we are the communicators of the information. We can turn data into a story. However, we can also move beyond informing and *influence*. We are there to help people understand something better in order to take action. We asked participants what an example of a take away or call to action could be – for instance when discussing the percentage of the federal budget space agencies receive during a planetarium show. A workshop participant said the call to action could be for audience members to write their local representatives.

I.1 When should we use data?

There is immense value in having visuals that make data accessible. Visuals help audience understand or remember and can help prompt recall. We provided participants with a few instances where data may enhance presentations. For instance, when you want to help your audience understand or remember. Or when your audience needs data. As in, do you need data to make yourself or the topic seem more credible? Does the audience need data to help them understand something better? Does the audience need see the authenticity of the information (to show validity of data or to remove doubt)? Also, you can use data when you want to make content more relevant to people, showing them connections to their day-to-day lives. We then opened the discussion up to participants on when we should use data, here are some of their suggestions: when teaching the scientific process and/or to show data that we do not understand (yet) to do science with the audience.

I.2 What barriers are preventing you from implementing data-driven presentations in your domes?

During the workshop we also discussed some barriers in the dome that prevent participants from implementing data-driven presentations. To start it off, we offered the barrier: it is hard to discuss content because it may come across as pushy or bossy to audiences when trying to tell them how to think or what their action should be because of the data. Some tips were given to help with this issue. For instance: greeting people while they enter the dome to make a personal connection at the beginning and/or adding stories of your own struggles or experience with changing personal habits due to data-driven choices to your presentations. Other barriers were: internet connectivity and audiences who don't seem to want an interactive experience (we suggest making use of the tips listed in Section II.2 to help with this).

II. WORKSHOP INFORMAION AND TIPS

The following resources and tips were provided to participants at the start of the workshop.

II.1 QUICK RESOURCES

http://visualizingscience.ryanwyatt.net/resources/
http://www.storytellingwithdata.com

II.2 TIPS TO MAKING IT LIVE AND INTERACTIVE

- Talk to your audience and ask questions, as well as answer their questions, to facilitate the learning process and turn your presentation into an interactive experience.
- Avoid getting caught up in the facts, figures, or data and check-in with your audience throughout the presentation. Use phrases that start with the following to help maintain a dialogue when presenting:
  - "I want you to do something for me…"
  - "I know that many of you may be thinking that…"
  - "Imagine if/what…"
- Be comfortable asking your audience questions. For instance:
  - Ask a question about their comprehension of the data early on. Ask if there is anything that you haven't yet said that would help them understand the data better.
  - Ask audience to consider/predict what would happen if _____. For instance, "what would happen if a trend keeps on going over the years in the data?"
  - Have the audience consider how the information affects them directly. Or ask, "how would it make you feel if…?"
  - Ask phrases like: "Given the data, what should be the course of action if…?"
  - Ask audience in a show of hands if what they saw/heard/experienced changed the way they think about something. Ask how they may change their behavior or take action based on what they now know.
  - Have your audience members make a statement, specifically committing to change.
- Challenge yourself to tell a story – don't talk yourself out of it unless that is what's right for the audience.
- Tell your audience what they should be getting from the data. Be direct. "Here is the data, and this is what you should get from it or how you should act based on it." This gives the audience something to react to and starts a conversation (even if they disagree). This is a conversation that often gets missed by just simply showing data.
- Create logical connections between parts of a presentation/story so you do not lose your audience. (These have to be connections that are logical to your audience and not just to you.)
- Use amazing visuals to "take" your audience places, creating an emotional and visceral connection (suspension of disbelief). This is a good hook that can lead to audience members exploring the topic more deeply on their own.
- When changing scale in visuals, include continuity to convey connectedness. For example, you can start at something on a human scale, then go to a larger regional and then global scale to explore large phenomenon.
- Include a personal story to help make you more relatable to your audience. (People enjoy learning from someone they can connect with.)
- Practice. Practice talking through data out loud. Practice telling/delivering a story.

III. WORKSHOP ACTIVITY

During the workshop, we asked participants to work on an activity. Groups were asked to pick a data set and then determine a "big idea" for a presentation. The "big idea" defines the purpose of the presentation, but does not just state your thesis – it inspires and creates action. The "big idea" should be a complete sentence. For example: if your data set is "cherry blossom data going back 1,000+ years" your big idea could be "Earth's climate is changing, but you can reduce global warming emissions to help."

III.1 Activity Questions

After groups had their data set and big idea, they then answered the following questions to build their talk:

1) Who is the audience and how is your story/data relevant to them?

2) What does your audience NOT know about the data? What do you want your audience to know?
3) How will you use data visualization storytelling and interaction to make your point? Be specific and list example phrases and/or questions you'll ask your audience.
4) How will the audience be able to use the information to make changes, reinforce habits, or spark conversation? What questions will you ask them to help foster these actions?

III.2 Audience responses

Fourteen (14) groups handed in their activity worksheets at the end of the workshop. You can find the scanned worksheets here: https://tinyurl.com/y7aagy52 or email dlthompson3@bsu.edu. To summarize, groups came up with the following data set/big idea examples to build their talks:

Group 1:
DATA SET: Earthquakes over time in US
BIG IDEA: We can use past earthquake locations to help predict future locations and you can take steps to help your community and selves to be safer.

Group 2:
DATA SET: Orbital trajectories of space junk
BIG IDEA: Human presence in space is cluttering up the near-space areas; how can we clean up after ourselves?

Group 3:
DATA SET: Microplastics
BIG IDEA: Microplastics affect living things, but we can still change.

Group 4:
DATA SET: Moons of solar system
BIG IDEA: You can discover clues to a moons origin based on its orbit.

Group 5:
DATA SET: LSST Alert Stream
BIG IDEA: We live in "the age of exploration" now.

Group 6:
DATA SET: Sea currents data
BIG IDEA: Europe's climate benefits from the warmth of the sea current; what happens if these would change?

Group 7:
DATA SET: Exoplanets
BIG IDEA: Everything we know about solar systems is wrong.

Group 8:
DATA SET: Gaia Data Set
BIG IDEA: How do you appreciate how large and populated the galaxy is?

Group 9:
DATA SET: Time sequences [] of a planetary nebula
BIG IDEA: Planetary nebula expands in 3D over human perceptions.

Group 10:
DATA SET: Catalog of bright galaxies
BIG IDEA: Show diversity of galaxies – classify, learn, identify.

Group 11:
DATA SET: Multi-wavelength observations of (astronomical objects) a dark clod against a starry sky.
BIG IDEA: Look at the world from different perspectives.

Group 12:
DATA SET: Health/deaths/life expectancy data sets and history and GDP
BIG IDEA: How vaccines have improved the world child death expectancy.

Group 13:
DATA SET: Earth at night map
BIG IDEA: We can waste a lot of light to space, so you can help by buying shielded lights.

Group 14:
DATA SET: Geography
BIG IDEA: Show different layers of data to different audiences, for example: atmosphere, vegetation, or soils.

IV. CONCLUSION

In one short hour, we got people thinking about how to think about their audiences and how to contextualize data to achieve desired outcomes, with an eye to making it interactive. We hope this is just the beginning to the design of more live and interactive data-driven presentations.

Artificial and real sky in Slovak Central Observatory in Hurbanovo

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BIOGRAPHIES

Marian Vidovenec – director general of Slovak Central Observatory. He have worked at planetarium since 1989.

ABSTRACT

One of the most important parts of activities of Slovak Central Observatory is the presentation of astronomy to the public. Basic program offer is divided into three basic topics. The first topic explains the history of the observatory to visitors in the context of historical science facts that had influence on the development of astronomy. The second part explains astronomy inside the planetarium under RSA skyexplorer3 artificial sky. This is a very good tool for explanation of the topics of astronomy which are difficult for people to imagine. Visitors like extraordinary imaginations of models that are offered by the planetarium, but sometimes they are a little bit confused especially when we try to explain how real astronomical observation are realised. The third part of our program offer is visiting the dome with real active telescope. There is a good opportunity to explain how astronomers work in real life. Visitors can see how astronomers have solved the problem with earth rotation, how magnification looks like or what can be dangerous during solar observations. In case of good weather, each visitor can take their own sky observation, during the day the sun and Venus and in the night much more planets, moons or deep sky objects. Our experience says that our visitors that come back remember better public observation than program under artificial sky. The best way how to explain astronomy is to use both artificial and real sky.

INTRODUCTION

Observatory in Hurbanovo was found in 1871 by Nicoulaus Thege Konkoly, who built it up at his private holding. From the beginning the observatory became famous by its scientific results on the fields of meteor observations, (he discovered meteor shower Alpha Ceapriconids in1871), solar observations, spectroscopy and photography. Observatory cooperated with schools in Budapest and Bratislava on preparing students for practical observations. The observatory was considered as scientific observatory till 1938, when its activity was interrupted by events of World War Second.
Activity of the observatory was reestablished in 1964 as a public observatory. Its activity was oriented mainly to public observations by 40 cm Cassegrain arranged under main dome. During programs for visitors staff introduced the telescope, its construction and possibilities of observation of heaven bodies. This is a base of program of all public observatories oriented to public observations by telescopes.
Since 1969 observatory in Hurbanovo has became Slovak Central Observatory under leadership of Ministry of Culture. Activities of the observatory expanded not only field of popularisation but on the scientific field too. Science program has oriented to solar observation on the whole scale. The observatory established magazine Kozmos that explains topics of astronomy to wide publlic and tries to attract people to amateur astronomical observation.

Nicolaus Thege Konkoly 1842 - 1916

Historical building of Slovak Central Observatory

1. Connection of ZKP1 sky with real

A big breakthrough came in 1983, when 6 m small ZKP1 planetarium was installed. Possibilities how to explain astronomy to public rapidly grew up. The staff of the observatory easily introduced to public the orientation on the sky, constellations, planets and deep sky object by slide show. Program inside planetarium corresponded with real sky and evening programs were sometimes connected with public observation. These connections were realised especially during some special events as Lunar eclipse, some comets appearances or some kind of stellar or asteroids occultation.

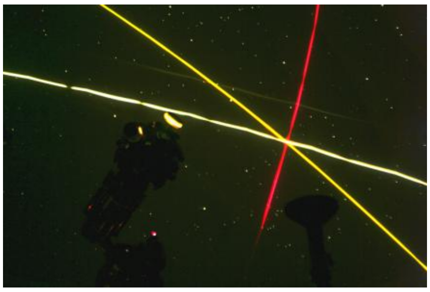
We noticed that public observation is sometimes more interesting and informative for public than common planetarium program. In the middle of nineties of the last century we started to connect our program in planetarium with explanation of instruments used by astronomers and public observations. During day there is not too much to show, but in case of good weather the Sun is suitable object how to entertain audience. A lecturer can show sunspots and facula fields on the surface of the Sun and he can connect it with talk about solar activity and space weather. But never forget, safeness of visitors is the most important. Sun is really dangerous object to observe. We use for its observation projection method that is provided in quite long enough distance from eyepiece. Of course we can show people easily by burning paper behind eyepiece, how dangerous the glance to Sun is.

During the day observation of the Venus is the best object to surprise visitors. A lot of people believe, that during daylight beside Sun there is just Moon observable. Nothing else is visible on sky. So we explain, that all object are visible in sky and the reason why we can´t see them is our atmosphere. In case of precisely aligned telescope we can show people some more bright objects on the sky.

Night public observation is more interesting by choice of the objects that lecturer can offer to public. From planets, through some nebulas, clusters Milky Way and galaxies. The old opto-mechanical ZKP1 was good to show where the object is but when we tried to show what the observer can see in eyepiece it was sometimes confusing, because we showed the shape of object on the other place by data projector.

Figures should be clear and the figure axis should be readable. The Figure title should be put below the figure.

Planetarium ZKP1



Planetarium ZKP1

Lunar eclipse

14´´ Celestron telescope

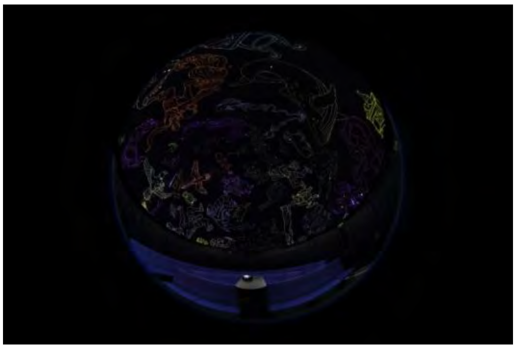
1. Connection of digotal sky with real

This changed in 2014 when Slovak Central Observatory installed digital projector RSA SkyExplorer3. The possibilities of animations and new models to explain astronomy rapidly grew up, but base of program seemed to be very similar we offered during ZKP1 era. We try to explain our nearest neighbours of our Earth, whole Solar system, planets moons etc. It follows night sky exploration, to show constellation its borderlines, shapes and deep sky object to belong them.

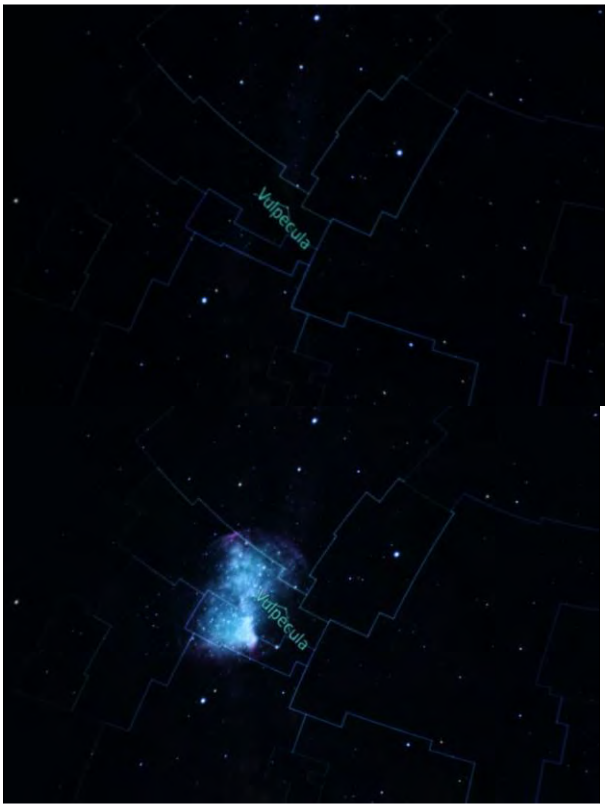
But in 2014 we put into operation our main Newton 40 cm telescope with goto mounting under 7 meters main dome. This telescope is used mainly for public observation. Our aim of the program offer is to provide each visitor to visit main telescope and be a part of public observation. Observation always depends on weather. In one occasion we do not open shutter of dome – rain.

Each program inside planetarium has a part of public observation preparation. We show audience actual situation on the sky, show object that will be showed in telescope. Digital planetarium is a very good tool to explain basic information about these objects. We show

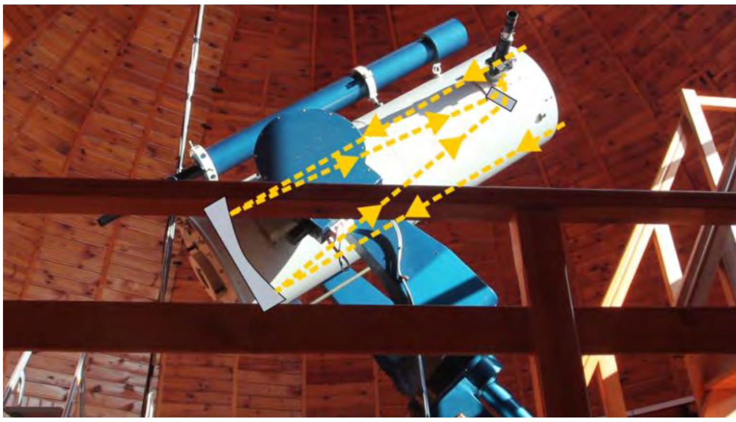
magnified objects on the right places, explain their attributes. For night public observations we prepared special script for each season. This script shows typical deep sky object especially from Messier Catalogue, that we can easily show to the audience. After this part of planetarium we show some fulldome film.
After planetarium show the audience move to so called historical building of the observatory where the big telescope is. For better comprehension how telescope works we prepared short film. This film explains the site of telescope, shows how mounting works and of course how we catch light by telescope.
After this briefing, our visitors move to the dome with telescope where skilled astronomer leads public observation.



Digital planetarium RSA Sky Explorer3

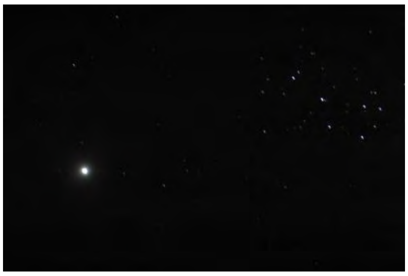


Dumber cluster on the right place



Scheme of Main 40 cm telescope

Main 40 cm telescope



View through telescope Venus with M45

ACKNOWLEDGMENTS

Our experiences say that people often remember much public observation part of program than a planetarium. The real sky with real gaze of stars is much more interesting than the artificial sky inside planetarium.
It is no doubt that virtual sky will improve and it will be more and more realistic. The connection with possibility of modelling known universe is breath-taking, but we have to remember that it is just a model.
The program under real sky shows people how we step by step improve our observation possibilities and that each model is created on the base of real observations of the real sky.

Citizen Science
(Poster)

Author= Karl von Ahnen, Director Emeritus De Anza College, President PPA,
vonahnenkarl@fhda.edu
Photography assistant, Poster illustration= Garth von Ahnen, ArtByGarth.com,
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BIOGRAPHIES

Author: Karl von Ahnen : retired director of the Fujitsu Planetarium at De Anza College, Cupertino, California; President of the Pacific Planetarium Association; Participating Photographer for Google/UC Berkeley Eclipse MegaMoviie

Illustrator: Garth von Ahnen -planetarium laserist, freelance artist, assistant on MegaMovie photography. artbygarth.com

ABSTRACT

Citizen Science
The "Eclipse Megamovie 2017" project sponsored by Google, the University of California at B erkeley and the Astronomical Society of the Pacific (among others) was a chance for anyone with the right equipment to become a citizen scientist. The organizers solicited over 1000 photographers across the US to participate in this very important data collection effort. By taking high resolution images with precise time and locations attached, it was possible to create a continuous movie of the event. This allows solar astronomers to study in detail, the coronal changes which took place over the 90 minutes of totality as the moon's shadow crossed the continent. Not only is this important data for the study of the solar corona, but it was a chance for many people to feel the excitement of contributing to scientific advancement - one of the goals of planetariums everywhere. As a bonus, this should be a very spectacular video for presentation in planetariums all around the world.
I would like to present a poster with some dramatic eclipse pictures and contact information for the Mega-Movie project, along with a short description of my experiences as a participant in this project.

INTRODUCTION

The following is the poster as presented at IPS 2018

Figure 1 – Text for

Poster as presented at IPS 2018, Toulouse France

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So you want to build a Planetarium?
Approaches and means of Strasbourg

Milène WENDLING, *University of Strasbourg Planetarium, France*

Email: milene.wendling@unistra.fr

BIOGRAPHIE

The author has a master degree in Astrophysics and planetology (Université Paul Sabatier, Observatoire Midi-Pyrénées, Toulouse). For 8 years, she worked in the planetarium team at the Cité de l'espace, managed by Marc Moutin. Since 2009, she has been managing the University of Strasbourg Planetarium part of the Jardin des sciences (JdS) department. She is currently involved in the new university planetarium project. She is the author of five popular science books on the astronomy for children.

ABSTRACT

A new planetarium for Strasbourg in 2021: the theater opened in 1982, and was at the time the 4th planetarium in France. The idea of a new planetarium in Strasbourg emerged in the early 2000s and the new one is due for completion in 2021.
What happened meanwhile, during 20 years ? What are the difficulties and the opportunities of such a project in the French context ?

INTRODUCTION

I work at Strasbourg University (Unistra) where I manage the Planetarium, a component of the scientific mediation department, the Jardin des sciences (JdS). For quite a few years now, my team and I have been working on the project of a brand new planetarium to replace the current one, in order to meet both our expectations and those of the public. In this submission, I would like to share with you our history and experience full of new developments.

I. NATIONAL AND LOCAL CONTEXTS

I.1 Scientific outreach in France

For more than 30 years, the French government has been supporting the circulation of scientific culture in France, in keeping with the initiative of Natural History Museums to popularize sciences. In the eighties, we saw the emergence of Scientific, Technical and Industrial Culture Centres, among which planetariums. Thanks to state and local authorities financial support, there are today, 30 big fixed planetariums in France, with a screen diameter greater than 6 meters.
In 1985, the national association APLF (Association of French Speaking Planetariums) was created in Strasbourg. It federates the diversity of french speaking planetariums and offers many opportunities for new planetariums in decades to come. This positive national context encouraged the emergence of the new Strasbourg planetarium.

I.2 Scientific outreach in Strasbourg

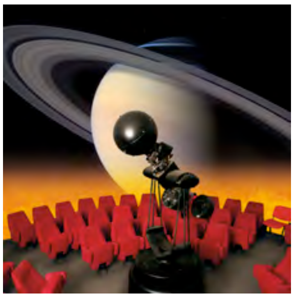
The local context is favourable: since the eighties, the Unistra Presidency has been supporting activities fostering dialogue between science and society. Not all universities in France receive such full support. We are lucky. Besides, the local authorities do fully support the project too, because the planetarium is a serious, relevant and useful scientific outreach place, well-attended since it opened in 1982, with about 30,000 visitors a year. For all these reasons, the idea of a new and larger planetarium emerged in the late nineties.
But, despite this very positive context, two former projects, in 2000 and 2005, failed because of financial issues and changes in political priorities at the Unistra. It's fairly common in France and maybe elsewhere too. At that time, we had to be patient, optimistic and rather confident because, in any case, the project of a new planetarium was already "in the box"!
In 2007, the French government published a real property call for tenders (called Plan Campus) and our university registrered for the construction of the new planetarium in the re-development plans of the campus. Two years later, in 2009, the planetarium team joined the scientific outreach department JdS (today 26 people), aiming at raising public awareness of sciences, in the past, the present and the future, providing a real boost for the planetarium team and its activities.

So now, why hasn't our new planetarium been built yet since 2007 ? This is due to french government funding, depending on circumstantial issues like, for instance, the french Presidential election and also the Unistra President election. The total cost of the project was scaled down, but fortunately today, we are now one hundred percent positive that the planetarium will open in 2021. You understand that you have to be very patient and flexible regarding public funding.

The Strasbourg University © Région Alsace- service inventaire

II. HISTORY OF THE CURRENT PLANETARIUM

The current planetarium is located in the Strasbourg astronomical observatory (ObAS). It was built during the German occupation in 1881, after the Franco-Prussian war, when Strasbourg became part of the German Empire.
Today, the ObAS is known as a top level research centre. In 1982, the astrophysicist Agnès Acker, driven by our national scientific culture dynamic, strongly supported public education on space and astronomy. She convinced the authorities to build an 8 meters planetarium in one of the observation rooms. It's the only university planetarium in France, integrated in the process of scientific research.
Its characteristics are 8 meters wide screen-dome, 62 seats, Spitz optomechanical projector, 30 000 visitors a year, diverse audience, outside activities.



The current planetarium with the Spitz projector © jds-unistra

Unfortunately, in 2014, the Spitz projector broke down and we had to close the planetarium theatre. And the new planetarium was far from being achieved. So we asked the Unistra to provide financial support to get a low cost home-made planetarium to continue our scientific outreach activities to the public. And it worked: we got 35 000€. We actually went for an alternative solution without the classic planetarium integrators. We didn't want to be dependent on a particular planetarium manufacturer and put our future choices for the new place at risk. Today we have a videoprojector Barco F50, 1600 pixels, fisheye objective, opensource software Stellarium360. After a year break and hard work with presenters, technical support and reception teams, our audience was very pleased by this projection option and by our programmes.
Since 2011, we have been seriously working on the new project. Today, the total budget for this operation (building, gardens and equipment) is around 8 400 000€ including 135 000€ for the equipment. This planetarium equipment consists of an astronomical simulator, screen dome, videoprojectors and computers, sound system, lighting, maintenance and production system.

III. A BRAND NEW PLANETARIUM

From the start, we knew that it would be impossible to expand our existing building. So we decided to choose a new place only 300 meters away, on the historical campus, surrounded by other university museums: Zoological Museum, Botanical Garden, Seismology Museum, Mineralogical Museum and near a tram line. The project includes the building of a new planetarium, the entrance hall for the activities of the JdS and renovating the historical gardens.

The architects *Frenak and Jullien* are based in Paris. The planetarium will be located in the truncated cone and the hall, in the flat cylinder. The architectural challenge was to include a modern building in a historical district.
The planetarium area is dark and the entrance hall is very bright. The interior design proposals comprise the planetarium, the welcoming desk, a waiting room, a shop, the rest rooms, and the cafeteria.

The new planetarium, the entrance hall and the gardens © Frenak & Jullien Architectes

IV. PROJECT METHODOLOGY

The schedule: it took 14 years between the acceptance of the project by the french government and the opening. We have never been so close to the end.

Launch of "Plan Campus"	2007
Agreement of our project approval	2009
Hiring of an Assistant for the building	2011
Final documents for the Ministry	2014
Hiring of an Assistant for the equipment	2015
Program for the architectural design competition	2015
Jury's choice for the architectural designer	2015-2016
Call for tenders for planetarium equipment	2016
Raising extra funds	2017
Working meetings with the architect	2016-2018
Call for tenders for the building work	2018-2019
Construction	2019-2020
Official opening	2021

The construction management team is structured in 2 committees: the technical committee and the steering committee.
For us, the technical committee is crucial. Although we have been running a planetarium for quite a while, we had the feeling that we needed new advice from the assistant to the project manager for modern planetarium equipment. *Jacques Guarinos* is a specialist of digital and modern planetariums, a precious help for making the right choices.

- **A technical committee**

Project manager
Manager of the planetarium
Technical manager of the Planetarium
Representatives of the university technical departments
Project assistants managers (for building and for the planetarium equipment)

- **A steering committee**

University Vice-President of built heritage
Director of the Jardin des Sciences
Director of university built heritage
Representative of the local authorities
Representative of the Ministry of National Education
General Director of the University

- **The Project manager**

The chosen architect manager
Her group of technical experts

In order to accommodate the screen dome, the projectors system and other technical requests in the new building, we have chosen the planetarium integrator 4 years earlier than usual. We wanted the planetarium integrator to interact from the beginning with the architect project manager.
Here are the technical options for our planetarium, mainly according to the budget and the university context, and the strong involvment of the technical manager of the planetarium *Benjamin Rota*.

- Screen dome 15 meters hanging: for future scaling up
- Oriented and tilted 18°: for best immersion
- Resolution: more than 4K
- Astronomical simulator: the most successful, versatile and scalable
- Laser projectors: lower operating cost
- Production system: to work on shows when the planetarium runs
- Guarantee and maintenance: 5-years cost assessment
- Lighting and sound system (with translation): for best experience

V. ISSUES AND ADVICE

I would like to outline the major stages of our project despite inevitable setbacks … some useful advice if you are involved in the building project of a new planetarium.
Pay particular attention to the following various points:

- Consider a 1,5 meter technical corridor behind the screen dome, for the video projectors, the extra material for special events and for future evolution of the projection system.
- The right position of the presenter desk, to the vertical line of the screen dome, for good eyesight of the sky and of the audience.
- A waiting room, in order not to overload the entrance hall between two planetarium sessions.
- Dark entrance and exit of the theatre to avoid light pollution during a session.
- Nearby rest rooms.

We had to spend several hours discussing the following issues with the planetarium integrator, the assistant and the architects:

- the tilt of the screen and the theatre for best immersion. We chose 18°.
- the smoke exhaust system consistent with the French standards.
- quick access of the computer room if there is a failure during a session.
- dust and air conditioning: in order to guarantee comfort to the public and to avoid dust on the screen-dome, we opted for a good distribution of conditioned air behind the screen. As a result, the dust will be trapped at the back of the screen.

Last but not least… constantly remind architects to keep within the allotted budget!

CONCLUSION

In conclusion, these practical tips certainly contributed to the success of our project: interact with your team if you already run a planetarium, visit others planetariums, hiring and assistant on the project (so precious) and invite for discussion many planetarium manufacturers before the call of tender.
In the french context, you have to be patient, positive and constructive to secure funding for such a project. It is a great adventure to set up such a new project and it is probably a once-in-a-life-time event.
Keep in mind that you work every day on the project to opening young people's minds to science and technology and developing a scientific and technical culture!

ACKNOWLEDGMENTS

Benjamin Rota, in charge of the technical management of the planetarium
Hugues Dreyssé, Director of JdS, Unistra
Marc Moutin, Exhibitions director, Cité de l’espace

Mireille Leyendecker for her unfailing support.

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Eyes on the Sky: Using Internet Resources and the Real Sky

April S. Whitt, Fernbank Science Center
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BIOGRAPHIES

I have a M. Ed. from the University of North Carolina: Chapel Hill, where I was selected as a Morehead Fellow in Planetarium Administration and Education. Currently at Fernbank Science Center, part of the DeKalb County School District, I've been fortunate to work at Adler Planetarium in Chicago as well.

ABSTRACT

In this part of the "Need Real Sky?" session, we will explore NASA's OWN telescope program for students to image the night sky and use software to create artwork, look for ISS passes, and share some images from International Observe the Moon night.

INTRODUCTION

Fernbank Science Center has found several successful programs for our public audiences.

Section I: Observing With NASA (OWN)

For over 20 years, the Harvard-Smithsonian Center for Astrophysics' MicroObservatory Robotic Telescope Network has allowed students access to a dark night sky. Arrays of remotely controlled telescopes capture images that students have requested. The images are sent to the students through e-mail. Students, teachers, and citizen scientists in the general public then use software to manipulate the images, measuring the size of the Moon at different times of night, observing Jupiter's features, comparing images of galaxies and nebulae, and gathering evidence for planet orbits.

The Network consists of five small telescopes, about a meter high, with 15 cm diameter mirrors, located at Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, and at the Whipple Observatory near Tucson, Arizona. They are operated through the World Wide Web. The telescopes are weatherproof and sit outside, requiring no protective dome.

Educational research on the project indicates that students and teachers who participate in these activities hone their project inquiry skills, as well as gain understanding in math and science concepts. "Owning" the image is important in engaging student interest. As users experiment with different filters and exposure times, they learn how to "fail instructively."

At Fernbank Science Center, we have used NASA's OWN activities with elementary and middle school students as art/science projects. Some of their projects are noted at the end of this paper.

A poster describing the educational aspects of OWN can be found at http://mo-www.harvard.edu/OWN/pdf/YAN_Poster2017_AAS.pdf

An article in the September 2006 issue of Astronomy Education Review, detailing how students and teachers use the telescopes, and how the activities impact learning is at http://access.portico.org/Portico/#!journalAUSimpleView/tab=HTML?cs=ISSN_15391515?ct=E-Journal%20Content?auId=ark:/27927/pgg3ztfbdch

Figure 1. Student's OWN art on display at Fernbank Science Center.

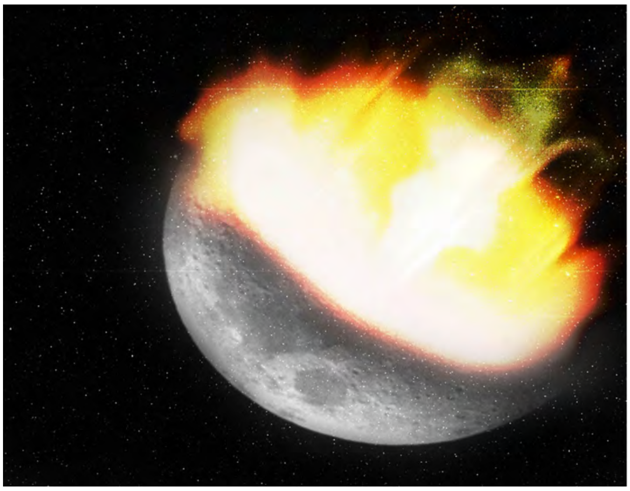

Figure 2 by Sydney

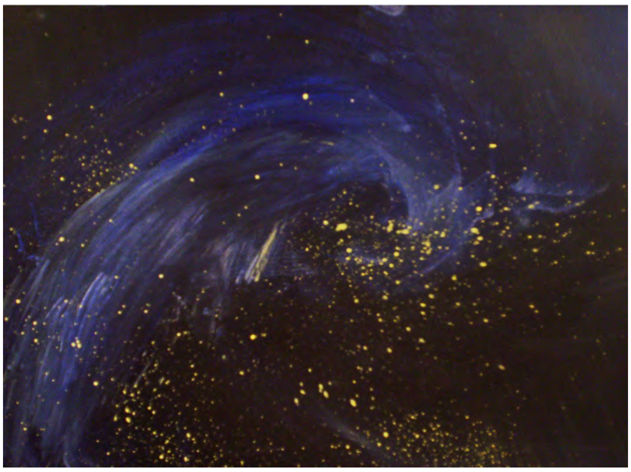

Figure 3 by Alex

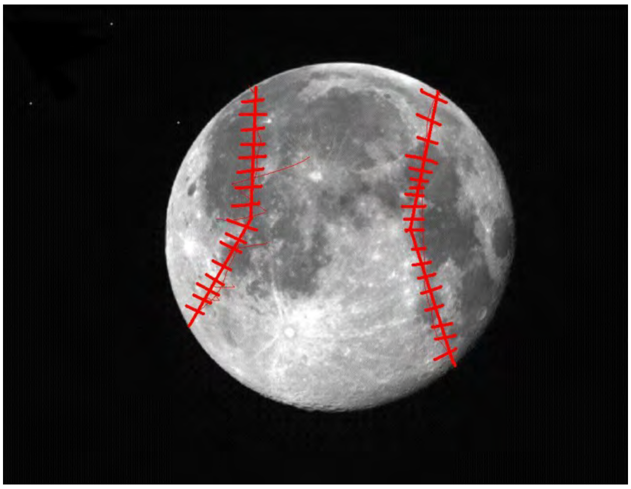

Figure 4 by Charlie

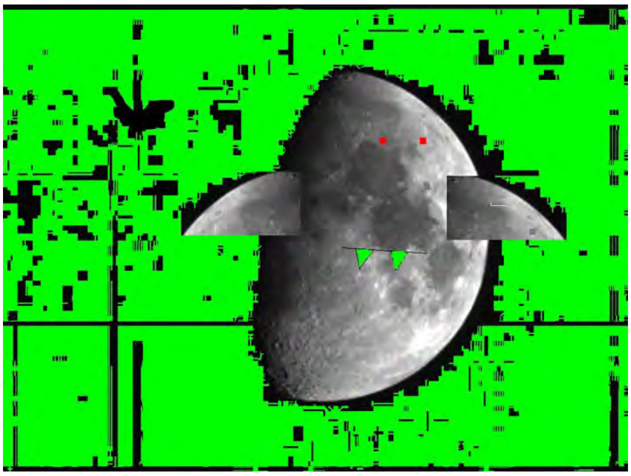

Figure 5 by Ryan

Section II: ISS PASSES

The International Space Station is bright enough to be observed even in the light-polluted skies of metro Atlanta. It appears to be the third brightest object, after the Sun and Moon. On several occasions, ISS passes have coincided with public observing nights.

I've pointed out the direction in which the station will become visible, and visitors have eagerly consulted their watches and the sky to see the pass. Applause and cheering have greeted the station every time.

A number of apps are available to alert observers to the next ISS pass. A good starting place for ISS pass information is at https://spotthestation.nasa.gov/sightings/index.cfm The web site https://www.heavens-above.com allows observers to input their location on Earth and receive a list of upcoming passes.

Section III: INTERNATIONAL OBSERVE THE MOON NIGHT

If you've ever set up a telescope on the sidewalk and invited people to look at the Moon, you know what excitement that generates. Humans seem enamored of our natural satellite. "Ooohs!" and "Ahhhs!" accompany an eyepiece experience.

Photography contests have been part of the event. We asked our visitors to photograph the Moon with a person in the shot for perspective, and to send their creations to us. People are always surprised to see how small the Moon looks in those images.

Several of the submitted photographs are included below.

If you are interested in sharing this experience with your visitors, this year's official International Observe the Moon Night is 20 October.

Figure 2. Cousin Antonio.

Figure 3. Fingertip Moon.

Figure 4. Chopstick Moon.

To Tell A Story

April S. Whitt, Fernbank Science Center
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BIOGRAPHIES

I have a M. Ed. from the University of North Carolina: Chapel Hill, where I was selected as a Morehead Fellow in Planetarium Administration and Education. Currently at Fernbank Science Center, part of the DeKalb County School District, I've been fortunate to work at Adler Planetarium in Chicago as well.

ABSTRACT

Would someone remind me of this, please?

INTRODUCTION

Storyteller Betsy Doty notes that, "If the history of the world were condensed to 24 hours, there would be 13 minutes of oral tradition, and .2 seconds of the written word."

Section I: Storytelling is important

Humans are social animals, and we've been telling stories for tens of thousands of years. Human brains love stories, rhythm, rhyme, and song. Mnemonic devices help us remember the order of the planets in the solar system, phases of the Moon or the bones of the skull.

We use stories to pass along values and ideas, to teach, to entertain. Story telling is important.

Research[1] indicates that when one reads a story in print, the parts of the brain that decode and make sense of language light up. But when one listens to a story, other parts of the brain are engaged, as well. A phrase like "the singer had a velvet voice," stimulates the sensory portion of the brain.

We've all told stories under the dome - stories in the stars. Many of us have researched mythology and stories from different cultures, to share with our audiences. Conferences are great places to hear sky stories and share them with colleagues. IPS offers resources on our web site.

At Fernbank Science Center, we've partnered with local storytelling groups. Members tell stories in our dome. We provide the science - they tell the stories.

Section II: Rules for finding and telling stories

Are there any rules about telling star stories?

In the United States, artists with stories in print or recorded media can copyright their work. They can claim ownership of an original personally created story, and register the work as theirs. Permission to use the story in print, online, or for personal gain requires permission from the author.

According to Heather Forest, "Teachers, librarians and educators working within the context of their jobs in an educational setting are free to use material that has a copyright without asking permission of the author." This is referred to as "fair use."

In telling stories from other cultures, it's important to do some research, particularly since many stories are part of an oral tradition. Some Native American stories are told only at particular times of the year, or by a particular teller. There are men's stories and women's stories in other cultures. Being sensitive to those cultures may mean choosing different stories to tell at different times or to different audiences.

An excellent resource for this is <u>The Storyteller's Guide</u>, by Bill Mooney and David Holt, published 1996 by August House Inc. Little Rock, Arkansas, USA, ISBN 0 87483 4821. The section in pp. 91-97 deals specifically with stories from other cultures.

Section III: Mythology

Carl Wenning, then director of the Physics Department Planetarium at Illinois State University in the U. S., shared some good points about storytelling. He pointed out that studying myths can be important on several levels.

Mythology can help modern day folk understand how the ancients relied on the earth/sky relationships for calendars and time –keeping. The sky can be used for direction finding; it is awe-inspiring and useful for recording events.

Myths are unique stories of unique cultures, and should not be thought of as "cute" or "meaningless." They explain relationships between creator and created (creation story), explain personal duties and provide role models (teaching tales), help to pass along tribal customs and moral truths, and can serve to continue oral history.

And they're simply good entertainment. Share some with your audiences.

ACKNOWLEDGMENTS

Carl Wenning, Physics Department Planetarium, Illinois State University, USA. "Understanding Sky Lore"

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The politics of fiction:
https://www.ted.com/talks/elif_shafak_the_politics_of_fiction?referrer=playlist-how_to_tell_a_story#t-1163778

Brain research op-ed piece at http://www.nytimes.com/2012/03/18/opinion/sunday/the-neuroscience-of-your-brain-on-fiction.html?pagewanted=all

1.

Copyrights and Fair Use article by Heather Forest at http://www.storyarts.org/articles/copyright.html

Kinesthetic Learning Under the Dome

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BIOGRAPHIES

Tiffany is the Planetarium Lecturer at Ward Beecher Planetarium at Youngstown State University where she coordinates all programs for the over 15,000 annual public and school group guests. She also produces live planetarium content for audiences of all ages and advocates for Cosmosquest, an online citizen science research center.

ABSTRACT

With the stunning visuals produced in planetariums, we are experts in visual teaching. But what about those who learn by doing? In this workshop we will discuss how people learn and how to use kinesthetic practices to engage audiences in a planetarium setting. Examples include introducing planets to 3-year-olds and explaining how we locate black holes to a general audience. Join us if you want to engage your guests in new ways and be ready to get moving with activities of your own creation!

INTRODUCTION

As the planetarium reaches its centennial, today's thousands of domes across the world continue to provide a unique and immersive experience for guests. With our roots deeply planted in the night sky, the learning potential of planetariums has only grown over time. Stunning visuals, unique and personal experiences with live programming, and the whole universe at our disposal, planetariums are powerful tools for communicating science and inspiring people of all ages and backgrounds. In order properly utilize that learning potential, programming in a planetarium should be as diverse as our audience.

Planetariums easily cater to specific styles of learning, but those methods are not always ideal for our audience. In 1983, Howard Gardner published a book detailing his theory of multiple intelligences. He claims that people have several different ways of processing information and separate them into eight primary categories: Linguistic, logical-mathematical, musical, spatial, bodily/kinesthetic, interpersonal, intrapersonal, and naturalistic. Today, this theory is criticized for its lack of empirical evidence (The Illusory Theory of Multiple Intelligences). In fact, some studies have shown that the theory of multiple intelligences does not hold up (Gardner's Theory of Multiple Intelligences: Myth or Truth?, 2018). Still, this theory changed the landscape of education as it critiques traditional measures like IQ tests. Gardner's theory shows that there is more than one way to teach and to learn. Other research-supported theories followed Gardner's theory, such as Constructivist teaching, which places the student in the center of learning (Brooks & Brooks, 1993) and multidisciplinary teaching, which suggests students learn best when approaching new material using a variety of methods (Greeno, Collins, & Resnick, 1996).

I. SCIENCE IS A VERB

Kinesthetic learning, or learning through bodily movement, can be a challenge in planetariums, which are typically dark with seats bolted to the ground. But science is verb; we learn and understand the world through experiment. Kinesthetic learning is a great way to engage your audience and put them in the center of the scientific process.

Some planetarium guests benefit from physical movement more than others. For example, young children learn best when they are using their bodies. David Kolb's experiential learning theory argues that children need to experience things directly in order to learn (Stice, 1987). Pre-K and kindergarten children in particular are natural explorers who find it challenging (and sometimes frustrating) to sit in a seat for an hour-long planetarium show.

This workshop explores different ways to modify planetarium programs in order engage kinesthetic learners of all ages. From simple tactics like pointing, clapping, and making animal sounds for constellations (Live From the Planetarium, 2013) to scavenger hunts under the dome, we will show that kinesthetic learning can enrich a planetarium show experience.

II. EXAMPLES INCLUDED IN THE WORKSHOP

II.1 Observing Black Holes

During her public lecture "Gasbags and Blowhards: Supermassive Black Holes in the Universe," Dr. Sarah Gallagher of Western University used a couple of glow sticks and a few volunteers to demonstrate how scientists study black holes when they cannot directly observe them. She placed a glow stick necklace around one volunteer labeling them a "star" and the other the "black hole". Then, with the all lights down in the planetarium, she asked her volunteers (a married couple she recruited before the show) to hold hands facing each other and spin in a circle. The audience could not see the black hole, but they could see that the "star" was orbiting something.

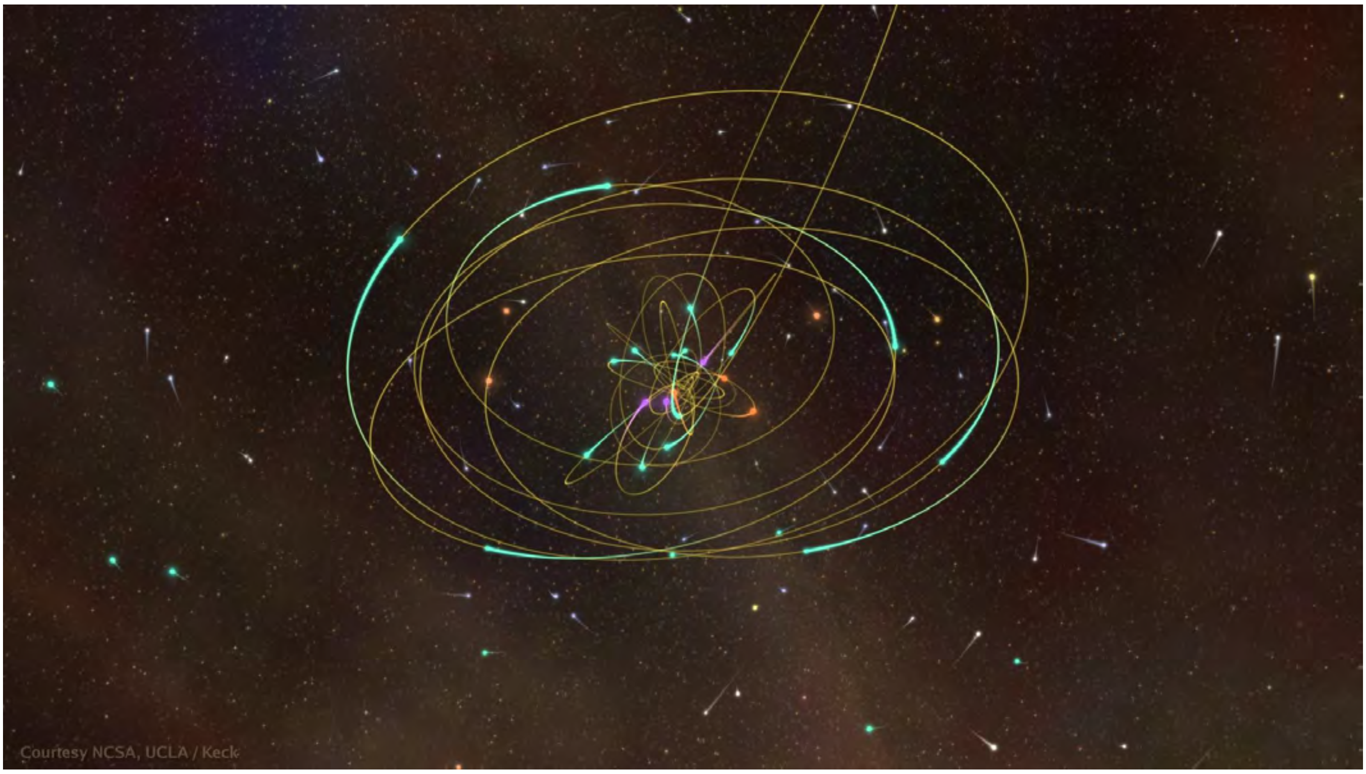

Figure 1 – Observing gravitationally bound stars around black holes

II.2 Space Shapes

Space Shapes is an hour long Pre-K show offered at Ward Beecher Planetarium broken up into 4 or 5 segments of 10-15 minutes each. It is built for the youngest guests and meant to have them explore the planetarium as they learn. The first segment of the show is the introduction where we discuss the planetarium, how the lights will sometimes be on, sometimes be off, and can be any color of the rainbow. We also discuss what we expect to see and do in the planetarium and introduce the "twinkling star sound," or a windchime which will signal the end of a segment and a time to refocus on planetarium staff to listen for what comes next. The windchimes are a direct application from the Montessori method and do a wonderful job at refocusing young guests with no dialog or raised voices (Montessori, 2015).

Figure 2 – "Twinkling Star Sound" to signal a new activity

The second segment is a shape scavenger hunt where visitors explore the planetarium to find hidden felt shapes. Once we return to our seats, we discuss shapes, colors, and 2D shapes versus 3D shapes.

Figure 3 – Guests explore the planetarium finding shapes in a scavenger hunt

The third segment is the 9 minute fulldome show, Space Shapes, produced as an open source show at Ott Planetarium by participants of the 2010 Blender Production Workshop. It is a fantastic, simple introduction to space and the planetarium.

Figure 4 – 2010 Blender Production Workshop planetarium show, "Space Shapes"

The fourth segment is an introduction to the planets where guests build the solar system from Mercury to the Kuiper Belt, learning a movement for each planet. All guests pretend to be the planets by going through each of the characteristic movements. Planet rotation causing day and night may or may not be mentioned.

Figure 5 – Planetarium guests learning about the planets

Figure 6 – Learning Saturn's characteristic movement

If time allows, the optional fifth segment is a brief star talk with introduction to the big dipper, north star, and possibly moon or planets will be shown. The house lights are never completely down and this portion will typically last no longer than 10 minutes.

III. OTHER EXAMPLES

III.1 Spacetime Simulator

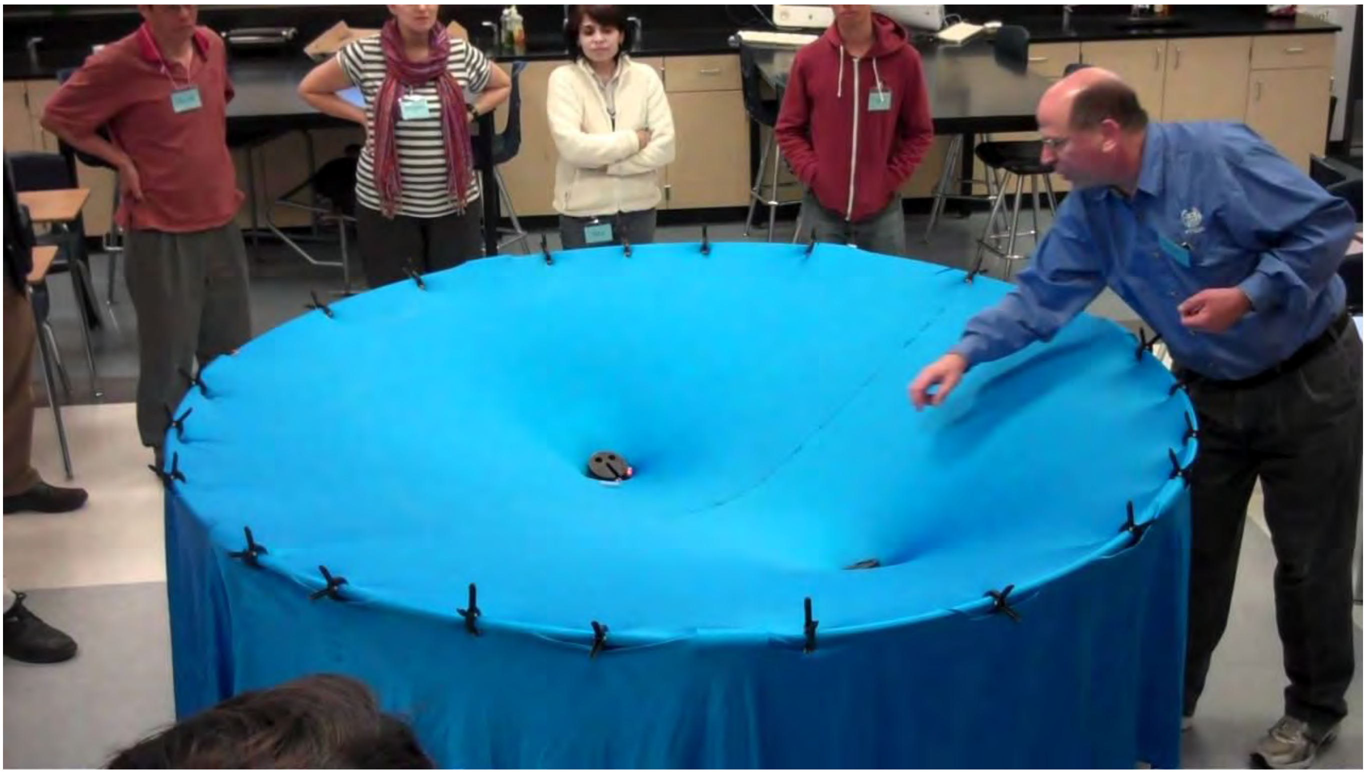

Figure 7 – Spacetime Simulator demonstrates the fabric of spacetime (See References for YouTube link)

IV. CONCLUSION

This workshop is meant to spur creativity in engaging audiences with kinesthetic activities under their dome. Planetariums are impressive education tools and their utilization is only limited by our imagination. Adapting to the learning style of our audience can enrich a planetarium show and create lasting memories for our guests.

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Laser shows and their challenges

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BIOGRAPHIES

I am a live show presenter in planetarium since 2014 and a laserist since 2016.
My task is to take care of laser system and laser shows in planetarium and also to learn software for creating laser shows. I have won ILDA award in 2017 for laser show 'My Sharona'

ABSTRACT

Lasers look really cool in the planetarium dome, but there are many challenges for it. You have to make it safe, you have to make it pretty and of course you have to make it work.
During the presentation I'll show you examples of how Heavens of Copernicus faces those challenges and what are do's and don't's with lasers under the dome.

I. WHY LASERS?

I.1 They are damn cool

This is not a big surprise. Lasers are awesome. That is a great reason to have them in your planetarium. Laser effects are a great way to express artistical beauty, delight audience and give this 'wow' effect.

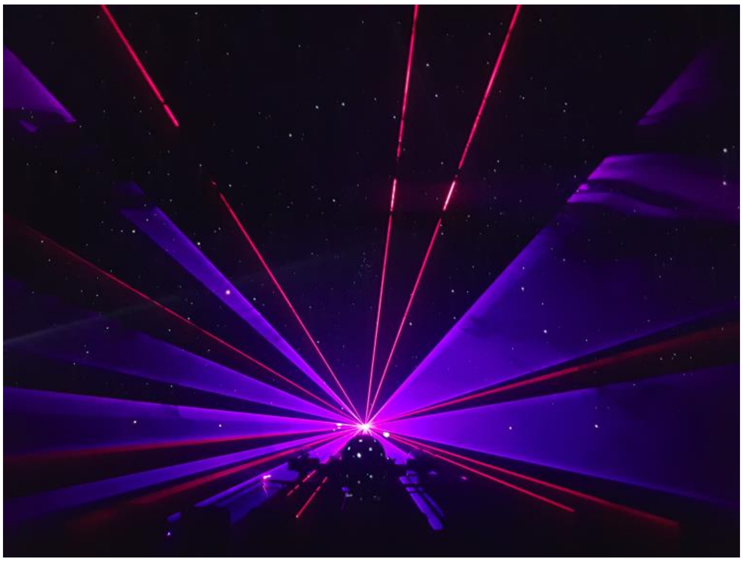

Figure 1. Lasers under the dome with Megastar IIA starball

I.2 They are popular and make good profit

Audience likes laser shows. Even though the ticket for a laser show is more expensive than for a regular show, they do sell better on average.
Based on data from May 2017 to May 2018, all evening shows, excluding concerts in planetarium, sell on average 67 out of 140 seats.
Laser shows sell on average 81/126 seats. (There are less seats for laser shows due to safety reasons)

I.3 It's fun to work with and easy to learn

Making laser effects and laser shows was one of the most fun experience I had as a planetarium employee. There are many cool laser effects you can can think of and test them, catch a great photo, make a musical laser show or just have a lots of fun. Software we use is LD2000 and Beyond 3.0 by Pangolin. There are many video and text tutorials for them. Beyond 3.0 is very intuitive and easy to learn. If you give yourself some time and patience, try a few things out – and if you'll enjoy doing it - you'll be a laserist in no time.

As a proof, below is a laser effect made in Planetarium by one of our presenters Bolek, who didn't know anything about doing lasers. After just 20 minutes and a little help from me he made this 'Birthday card' for his friend.

Figure 2. Laser 'Birthday card'

I.4 Events

You can use lasers for many occasions. The most obvious are of course special laser shows you can have in your repertoire, but you can also have live concerts with lasers or you can make a short laser shows which you can then include to your other special shows, for example I made 4 minutes long laser show 'Polakow' which was displayed after every show on 7th March, which is ILDA's International Laserist Day.

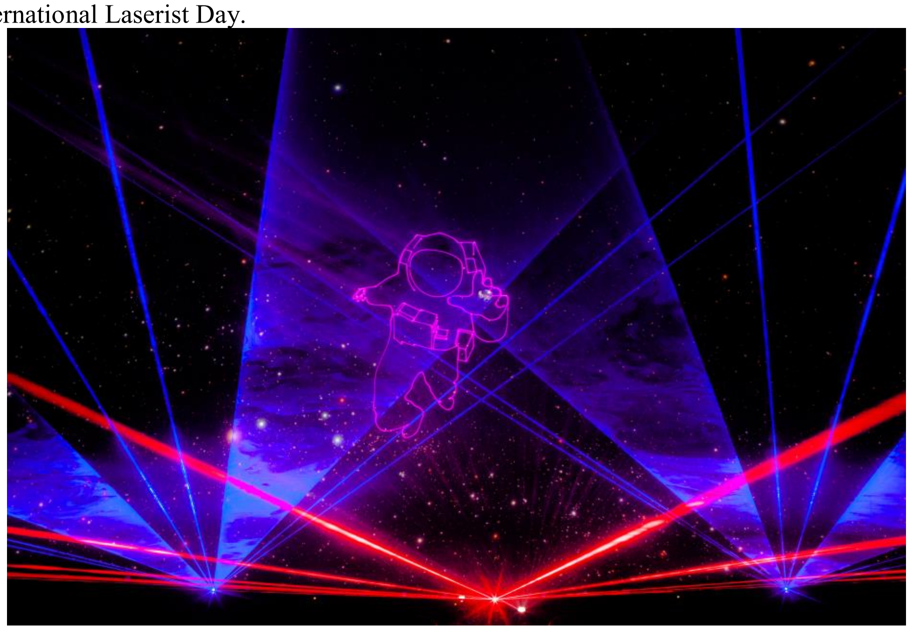

Figure 3. Frame from laser show 'Polakow'

I.5 International Laser Display Associaton

You can be a part of a community, similar to IPS but for laser industry. It is very good to build contacts, be in touch with new things in the field, get help and advice and every year you can send your laser shows to ILDA Awards contest.
Not many planetariums participate…

II. CHALLENGES

II.1 Safety

Since laser beams are, generally speaking, unsafe in contact with eyes and even skin, your job as a laserist is to make your lasershow safe.
You have to consider a few things when thinking about laser safety:

- Power density of a laser beam. Any beam that can hit the eye should be below 25,4 W/m^2 which is considered as MPE (Maximum Permitable Exposure). If you want to use audience scanning effects, this is very important!
- Distance of laser projectors to the audience. ILDA standard says laser projectors should be in a distance of at least 2.5m of any member of an audience. Because of this reason, we had to exclude the first row from any laser show.
- Your laser installation should have some safety devices. Some are considered obligatory such us interlock key, safety power cut off button.
- Safety procedures. Using safety gogles while testing, briefing the audience about laser safety, warning signs.
- Law. Law considering laser shows vary from country to country. Sometimes it's very precise, sometimes it's very opaque or even it's not existing. ILDA rules about safety is a great guideline on how to make your lasers safe, specialy if law in your country is silent about it.

II.2 Installation

Laser system is made of many elements. Besides laser projectors there are also fog machines, software and hardware for controlling the lasers, safety devices (e-stop buttons, interlock key, sensors, lenses), timecode devices if necessary, reflective and diffractive mirrors. Those things are costly. As an example, laser system in our planetarium cost is about 70 000 $.

While installing laser system you have to keep some things in mind.

When installing laser projectors, besides safety directives, you have to think about how you are going to use lasers. There are two basic kinds of effects with lasers: graphic and atmospheric. Graphic effects are images displayed with lasers. You can easily make sillhoutes, raster graphics or abstracts. You can also use 3D models for it. Animations are possible too. Atmospheric effects are much more effective. These are laser courtains flying above the heads of the audience. We mount our projectors at the bottom of the dome screen. We have 5 projectors mounted in front of the audience – for atmospheric effects – and 3 projectors at the back – for graphic effects. One thing that bothers me with our laser system is that I cannot access all dome screen with lasers. My 'projection zones' miss few parts of the screen.

Using fog machines makes atmospheric effects visible. We have 4 fog machines: 2 in the front and 2 in the back. Although theoretically many fire sensors don't raise alarm when using theatrical fog, we found that it is actually possible. We have a procedure to turn off fire sensors for duration of laser show.

Safety devices are various. Some of them are obligatory, and when installing laser system you have to include them. These are: interlock key, safety emergency buttons (with a key). But you can have some more, for example we use a sensor that detects if anyone in the audience has stood up. If so – the sensor turns off the laser projection.

For more effects you can use mirrors. Reflective mirrors are used to bounce a laser beam, diffractive mirrors split the beam into many, creating nice effects. We have mirrors attached to the bottom of the screen dome. In my opinion, mirrors are a little bit overkill. Effects they produce are not that astonishing, and mirrors seem to be problematic. If any mirror flips it can make a laser beam hit the audience. Therefore they are tested before every show and if there is a problem you have to do something about it. I personally do not recommend using them in planetarium.

II.3 When working with lasers

Preparing for the laser show is very important. Laser show is built from many blocks and you have to make sure they all work fine before you start the show. Therefore it is good to have some time for it. 45 minutes seems to be optimal, anything less than that might turn out to be problematic. If the system works fine, 15 minutes is enough. But if there are any problems – that would be very stressful. That's why I recommend at least 45 minutes. Our experience shows that this is a good solution.
And what do you have to test?
If lasers, fog machines, safety devices, planetarium system works correctly, if timecode is being sent (if you are using it), if mirrors or lasers didn't flip which is very important because of safety.

You have to remember about your safety procedures: turning off fire sensors, using safety gogles and briefing the audience about a laser show: you should inform them that the theatrical fog is being used, that there are (if there are) audience scanning effects, and what will happen if they stand up, where is the exit of the dome etc.

III. SUMMARY

That all being said – lasers are worth the effort! Many ILDA members I have met during the ILDA Conference told me that they first encounter with lasers was in fact many years ago in planetarium. And it was inspiring enough to make them dedicate their lives to it.
First laser shows in the world, created by Ivan Dryer, were in fact planetarium shows. It's a great legacy that is somehow missed nowadays. Out of 538 planetariums in data of online search tool plafinder, only 10 have laser system.
I'd love to see more planetariums with lasers and I'll be happy to help you with artistic side of it: to show you the software and help you create shows.

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www.pangolin.com Homepage of our laser software developers.

www.plafinder.com Planetarium search tool

Space Tours Live! Audience Choice for a Live Planetarium Show

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BIOGRAPHIES

Ka Chun Yu has developed real-time interactive planetarium visualization software; been involved in live and pre-rendered fulldome show productions; given hundreds of public lectures, professional development programs, classes, and media appearances; and researched the use of digital planetariums for astronomical and Earth systems education.

Naomi Pequette is an Earth and Space Science Programs Specialist at the Denver Museum of Nature & Science. Her focus is developing space science demonstrations, facilitations, and live planetarium shows, as well as training staff and volunteers. Naomi holds a B.S. in Physics and Astrophysics from the University of Denver.

Samantha Sands is an Earth and Space Sciences Program Specialist at the Denver Museum of Nature & Science. Samantha earned her Master's in Museum Studies from the University of Colorado and her Bachelor's in Environmental Geology from the University of Michigan. She develops programs and trains staff and volunteers in exhibits as well as live planetarium programming.

Dan Neafus has produced engaging audience experiences for 40 years. As executive producer, his fulldome works include *Black Holes: The Other Side of Infinity*, *Bella Gaia – Beautiful Earth*, *Super Volcanoes*, and *Dynamic Earth*. Dan is a frequent speaker at international conferences focusing on "The Language of Immersive Cinema" and fulldome business cooperation.

Greg Mancari has worked at the Gates Planetarium for over 10 years and has helped to develop and present successful programming including Astronomy Learning for Immersive Virtual Environments, the Worldviews Network, and *Space Tours Live!*

ABSTRACT

Space Tours Live! is a guest-driven, live interactive digital planetarium show at the Denver Museum of Nature & Science's Gates Planetarium. A host guides the audience on their journey following one of three different programmatic outlines, but using requests from the crowd to build a show narrative that appears fresh each time. After initial conversations with visitors, the host picks the theme of either "Cosmic Distance," "Habitability," or "Cosmic Collisions." The guests also suggest places in the Solar System they would like to travel to, and these locales plus answers to audience questions are woven into the story. The presenter builds a coherent narrative by relating information specific to the chosen theme for each body encountered. We describe how our presenters—many of whom do not have astronomical backgrounds—trained for these multiple storylines, discuss the public feedback from our ongoing evaluation, as well as the lessons learned from the development of this program.

INTRODUCTION

The first planetarium audiences in 1920s Germany saw classroom-style lectures and demonstrations from planetarium directors who were former university professors. Later shows evolved to be less didactic and more appropriate for general public audiences (Hagar 1973). The combination of visuals from a planetarium projector and narration from a live presenter became the initial model for the "star talk" in a dome. However, by the early 1950s, planetarians, like Richard Emmons, were experimenting with taping presentations for playback (Emmons 2005). Planetarium staff now began to record their best in-house presenters. Instead of being lucky enough to catch a first-rate lecturer on her finest day, anyone attending a planetarium show could now hear the best "take" from the talent.

Show recording and playback was a widespread enough phenomenon that by the 1960s, there were debates over whether taped or live programs were more effective (Friedman 1991). Over time, larger planetariums began to hire outside celebrity voices for their show recordings. In 1973, the Miami Planetarium had a recording session with 17 actors, including *Star Trek*'s Leonard Nimoy (Geoghegan 1973). The final audio tracks, which included music and sound effects, were bundled with annotated scripts and slide projector visuals for rental or sale to other planetariums (Gronauer 1978; pp. 160-161). Although sharing show content had been discussed by planetarium directors as early as the 1950s (Marché 2005, pp. 107-108), it was not until the 1970s that show distribution of this type became common. The Strasenburgh Planetarium in Rochester, New York and the Hansen Planetarium in Salt Lake City, Utah were the two most prominent institutions distributing pre-packaged content nationwide to other planetariums (Marché 2005, p. 172). Science fiction adaptations were a popular genre. Fred

Hoyle's novel *The Black Cloud* appeared at the Hansen Planetarium in 1969 (n.a., 1974), while Isaac Asimov's classic 1956 science fiction short story *The Last Question* appeared as a co-production from the Strasenburgh and Abrams Planetarium (in East Lansing, Michigan) in 1972, and was sold to other theaters for $825 (n.a., 1972).

The evolution of "canned" programming turned next to the development of fully automated systems, where a single operator could control the audio and visuals for an entire show. Triggers for the slide and special effects projectors were recorded as inaudible cues on the same magnetic tape as the audio narration. The all real risk of a tape breaking in the middle of a performance meant that early computer control systems were created to run multimedia (Wieser 1977). Many planetariums had a mix of both live and canned programming. Charles Gronauer reported that each of the Strasenburgh Planetarium's nine pre-recorded programs had a live introduction by a host who would explain the planetarium technology and answer any questions before the canned show was played back (Gronauer 1978, pp. 164-165).

For the last 70 years of their existence, planetariums have had two competing philosophies for delivering programs. The first and more traditional mode was with a live lecturer, who could provide spontaneity and interaction with an audience, and who could tailor each program to the specific needs of the visitors in the theater. The second mode was via a narration track recorded by a polished presenter, augmented by music and sound effects, and which could be played back repeatedly day after day. Many planetariums did not strictly adhere to one paradigm over the other. Instead, planetarium directors understood that pre-recorded and live programs both had their merits. The decision to pick one over the other was based on multiple considerations, including the objectives of the program, the intended audience, the number of times the program would be repeated, the complexity of the show, and the reliability of the playback equipment (Del Chamberlain 1972).

I. THE BENEFITS OF LIVE VS. PRE-RECORDED NARRATION

This tension between live and canned programming continues to today, although there is a strong recent movement to highlight and disseminate the best of live interactive presentation techniques (Berglund 2011). Video playback in modern fulldome planetariums has advanced so that a lone individual, with no training in astronomy or even the operation of the real-time simulation software, can push a button to start a program. Senior management worried about the balance sheet would see such automation as helping to keep the planetarium financially afloat, while other planetarium staff could counter-argue that there are substantial benefits from a live program. Unfortunately, this latter assertion is almost entirely anecdotal, because there is no published research that makes a straightforward comparison of these two delivery practices.

An unpublished visitors study report from the Denver Museum of Nature & Science (DMNS) however shows the clear benefits of a live program over its canned counterpart (Koke 1999). Sixty visitors were shown one of two shows on asteroids, comets, and meteors, with the same script, but with the narrator performing live in the Gates Planetarium in one, and heard via a recording in the second. The show explained five different actions the audience could take in case they saw a meteor in the sky. In the post-treatment survey immediately after the program, visitors were asked how many of the five actions they could remember. Those who saw the show with the live narrator tended to remember more actions (Table 1). A greater fraction of the live audience compared with the pre-recorded audience could recall each of the actions (Table 2).

Table 1 – Number of Correct Responses from Visitors (from Koke 1999)

	Recorded Show	Live Narrator
0 correct	20%	5%
1 correct	32%	11%
2 correct	29%	32%
3 correct	12%	47%
4 correct	7%	5%
5 correct	0%	0%

Table 2 –Visitors Recalling a Specific Action (from Koke 1999)

	Recorded Show	Live Narrator
Keep eyes on object	5%	26%
Use fist to measure	51%	68%
Note time/location	51%	94%
Note presence of sound	17%	39%
Note direction of object	16%	29%

Visitors from the live show were all aware that they had witnessed a program with a live narrator. Interviews with the presenters suggest that even in a darkened theater, the audience could hear subtle cues that the presenter was in the room, including soft breathing and clearing of throats. The presenters also believed the audience was aware of them shifting their positions inside the theater. From their interviews, visitors felt the live narrator to be more personal, and was speaking to them directly: "I would say the difference between a live narrator and a canned one is like when a human answers a phone, rather than an answering machine."

Four planetarium staff who participated in the study were also asked about what they thought was happening during the live presentations. Because they were in the same room as the crowd, the presenters believed that a "conversational dynamic" was established between them and the audience. After being subtly conscious that they were part of a conversation, the audience became more attentive and involved as part of the expectations of being a partner in an oral exchange, even though they may not actually have spoken up during the program. Furthermore, the presence of a narrator created an "illusion of the first time:" the audience felt that the engagement was unique and tailored for them alone, making them feel special. The study inferred that the pre-recorded show audience was not affected by these factors, leaving them less engaged and attentive.

II. COSMIC CRUISIN'

Despite this strong evidence for the utility of live over canned programs, DMNS management made the decision to have only film playback when the Gates Planetarium reopened after its remodel into a fulldome theater in 2003. The theater seat-count shrunk because of the new uni-directional seating layout within a tilted dome, which meant that the each show would have only a half hour turnaround. There would be insufficient staff available for such a fast-paced schedule of programming.

Instead of a strong director, DMNS planetarium programming decisions are made by an operations team consisting of staff from multiple departments: Planetarium Operations, Research & Collections (for scientific review), Programs (for educational review, performer staffing), Guest Services (for ushers and ticketing), and Marketing. The cross-departmental nature of dome theater operations means that the development of new shows—especially ones that break from the default playback mode—must involve and have support from multiple divisions in the Museum. Therefore, new live programming faced a number of different barriers. In the past, the Programs division did not have enough staff to cover the daily shows. The Marketing department was concerned about the consistency and quality of live presentations; they expected each Educator Performer's[1] performance to meet the same high standard of excellence. Even the Finance department expected that ticket sales from a new live show to at least match, if not exceed, the revenue from an existing show that it was replacing in the same time slot.

Despite this, Planetarium staff (including authors Neafus and Mancari) and Programs staff had long been interested in reviving a live program at DMNS. Assistant Coordinator for Space Gallery Programs Dave Cuomo began prototyping a free program called *Cosmic Cruisin'* in late summer 2009 using an open half-hour block during lunchtime. It would feature SCISS AB's Uniview software, which was already being used in Gates Planetarium evening programs. As a staff educator delivered the live presentation while mingling with the audience, a second person would "fly" Uniview in the dome. This operator was initially a Museum Galaxy Guide volunteer docent, who had experience with the software on the *Orbits Table* tabletop interactive in DMNS' *Space Odyssey* exhibit. (Eventually, Programs staff eventually took over this role as well.)

Instead of a traditional star talk, *Cosmic Cruisin'* quickly evolved into a free-form program, where audience feedback was essential for shaping the narrative. The presenter asked visitors where in the universe they wanted to go or what they wanted to see. Audiences tended to ask for flights to different worlds in the Solar System, as well travel out into galactic and extragalactic space. Some presenters opted to emphasize what was visible in the night sky, but the show mostly focused on simulating space travel to locations throughout the universe.

The *Cosmic Cruisin'* presenters eventually included not just the staff educators, but also talented Galaxy Guides and DMNS scientists. Generally, staff educators were discouraged to go outside the Solar System since were not knowledgeable enough to talk comfortably about galactic and extragalactic astronomy. However, there were researchers or talented volunteers who could address visitor questions in those domains. Themes would emerge for each presentation depending on the expertise and interests of the presenter, including observational astronomy, astrobiology, and even talks by a geologist focused on Earth features visible from low orbit.

For the first year of the pilot phase, the only way that visitors knew *Cosmic Cruisin'* was happening was if they happened to walk by the open doors of the planetarium as the presenter pitched the program like a carnival barker, in the few minutes before the show started. By the following summer in August 2010, staff had enough experience that *Cosmic Cruisin'* appeared on the regular planetarium schedule. Although there was some discussion about switching to a paid ticket model, the show was kept free for the public. At this time, in addition to its regular lunchtime slot, *Cosmic Cruisin'* also began appearing as an offering during evening Members Nights and other special events.

III. GENESIS OF SPACE TOURS LIVE!

In November 2015, the Gates Planetarium began running Adler Planetarium's *Destination Solar System*, a hybrid program with a presenter who interacts with a character in the fulldome film, thus combining the engaging presence of a talented performer with the polish and consistency from a pre-rendered film. Although *Cosmic Cruisin'* had been successful the previous five years, it was discontinued as a daily show in order for it not to compete with a live program that was generating ticket revenue.

In the year after this changeover, *Cosmic Cruisin'* did not entirely go away. In the *Space Odyssey* exhibit, staff Educator Performers hooked up a Uniview-enabled laptop to the 3.6 meter-wide, flat "Space Screen," to run "Travelin' the Universe," a

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[1] At DMNS, Educator Performers have communications training, and often come from acting or improvisational backgrounds.

variant of *Cosmic Cruisin'* with more night sky and constellation story content. A version of *Cosmic Cruisin'* in the dome also appeared in an evening, adults-only event, the *Great Space Escape*, which involved a host of other space and astronomy live programs and activities in addition to the dome show. There were even occasional queries from daytime guests wondering what had happened to the regular *Cosmic Cruisin'* offering in the planetarium. Despite the lack of a daily show, the variations on the *Cosmic Cruisin'* theme proved popular enough to ensure that it would eventually be resurrected in a new form.

Planetarium staff continued to investigate how *Cosmic Cruisin'* could be revived, and submitted several proposals to DMNS leadership for funding to develop a new program. In December 2016, approval was finally given for a follow-up, with 8-weeks allotted for development starting in January 2017. Now known as *Space Tours Live!*, the new program would have several essential elements. It had to be a high quality, consistent experience for audiences, regardless of who was delivering it. The technical aspects of running the program would also be smooth and invisible to the audience. The Educator Performers also had to be focused on their presentations, and not distracted by the user interface, the workings of the software, or the underlying hardware.

III.1 Storylines

The free-for-all nature of *Cosmic Cruisin'* meant that the Uniview operator ended up hopscotching around the Solar System (and sometimes the universe, depending on the presenter) based on audience requests. This often resulted in a disjointed performance, and not as polished and professional as a live program could be. Another challenge was to create a satisfying storytelling experience with a beginning and end, but which still incorporated the open-ended audience requests. A free-form audience-driven show meant that different presenters with their own content knowledge and experience with astronomy and planetary science would create a broad range of experiences for their audiences.

We decided to create three different pre-defined storylines for *Space Tours Live!:* "Cosmic Distances," "Types of Planets in the Solar System," and "Habitability." The scripts for the first two were completed by mid-February 2017, with the final story done a month later. Each narrative would be supported by examples from places the audience requested to visit. Guests would feel that they were experiencing a wholly audience-driven show, even though the narrative was actually constrained. At the same time, the audience experience would be more polished and narrative-driven than *Cosmic Cruisin'*. Five years of running *Cosmic Cruisin'* let us know what the most common audience questions were. For instance, we received requests for the same Solar System objects (Mars, Saturn, Jupiter, Uranus, and Pluto). There were few quantitative questions like "how hot is it?", or "how far away is it?" Instead the frequently asked questions were ones involving origins ("Why is it rocky?", "How did it get there?"), human space travel ("Have people visited Mars?", "When are they going there?"), scale ("How big is it?"), and questions about specific objects and features (e.g., Saturn's rings, Jupiter's Great Red Spot).

III.2 Training

A cadre of twelve Educator Performers were delivering *Destination Solar System* shows four times a day. This team were chosen also for *Space Tours Live!* These presenters came from a larger pool of 30-40 part-time Educator Performers, who operated throughout DMNS in exhibit gallery programs, on- and off-site school programs, evening events, and in-house science camps for schoolchildren. Most had performance and/or teaching backgrounds. Although they may have had experience working in other DMNS educational programs, they did not necessarily have any astronomy training. (One performer admitted that he did not know the names of the planets in their correct order when he was hired for *Destination Solar System*!) Despite the initial varying levels of ability, all of these Educator Performers shared an innate curiosity, a willingness to learn, and the ability to convey excitement about science to their audiences.

Many of the Educator Performers training for *Space Tours Live!* had space science content training from working in the *Space Odyssey* exhibit. There they also picked up Uniview skills by delivering the "Travelin' the Universe" version of *Cosmic Cruisin'*. Such interactions were important, since they were used to delivering only scripted responses in *Destination Solar System*. Those who did not have any Uniview-related experience started practicing their presentation skills with the "Travelin' the Universe" talk or on the tabletop projection *Orbits Table*. Such activities were low risk, since DMNS guests were not paying any additional fee for such programs (whereas they normally would in the planetarium). Audiences would be more forgiving of mistakes and glitches. The Educator Performers were also gaining experience by having authentic interactions with guests, which would be more difficult when practicing with other staff members. Some performers also practiced in the planetarium itself, working in the dome before or after the daily public shows.

Educator Performers who had little astronomical backgrounds had the greatest challenge, since they had to appear as experts to the public. Program specialists (authors Sands and Pequette), who were responsible for training, provided them with educational content sheets, pointed to NASA websites, and sent them to watch the Crash Course Astronomy videos hosted by Phil Plait on YouTube. Educator Performers were also encouraged to prepare with one another via mutual discussions and quizzes. Most of the Educator Performers actively sought out new content knowledge on their own, even after their official training ended, so that their shows would stay fresh.

The Educator Performers also covered programs throughout the building, so training had to accommodate their existing work schedules. With a dozen staff to prepare, a detailed calendar was developed to allow time for instruction, rehearsal, and final sign-off by the program specialists. Each Educator Performers had 1-2 training sessions in the Gates Planetarium, where they were able to practice operating Uniview using the Panels interface on a handheld tablet, and playing to an audience consisting of other staff. In addition to making sure that they were able to perform at least one of the storylines, they also practiced handling situations where an audience member presented them a question they did not know the answer to. The goal was to have all staff gained the same comfort with the technology, and the same competency in content knowledge needed to deliver the storylines. As they improved their skills, the Educator Performers also had to make sure their enthusiasm for the topics and the spontaneity of their performances—necessary for audience engagement—did not wane. They were still expected to meet the high audience expectations for live presenters at DMNS. By the end of the in-dome training sessions—typically 2-3 weeks after training started—they were signed off by the program specialists.

III.3 Technical Operations

Uniview can be controlled from a tablet with the user-programmed Panels interface. These easy-to-create layouts allowed the Planetarium Technician (Mancari) to create a unique interface allowing Educator Performers to swipe back and forth between different pages for the *Space Tours Live!* storylines. Each page was designed to be sparse, to minimize confusion. Notes containing additional information were found on each page. The deliberately simple interface was meant to accommodate Educator Performers with a range of technical ability, from those who were technically savvy to those not comfortable with computers. The tablet also allowed the Educator Performer to control the dome while standing visibly near the audience, instead of being tied to the control desk in the back of the theater. Overhead lighting was left on at a subdued level initially for the audience to see the presenter, but was turned off afterward to maximize the impact of the dome visuals.

The Gates Planetarium runs Evans & Sutherland's Digistar software for pre-rendered show playback, while Uniview is used for real-time presentations. The Educator Performer staff were given instructions for switching the dome between playback and the real-time systems, as well as toggling a KVM controller so that the keyboard and mouse governed the appropriate cluster. For each live show, the Educator Performer donned a headset that fed the microphone audio to the dome sound system. A hand strap attached to the tablet allowed it to be held with one hand, and controlled with the other. Background music came from a second tablet which started playing before the start of *Space Tours Live!*, and unplugged afterwards when the dome went back to show movies. A procedural checklist helped staff complete their tasks in the proper order.

Technology-related problems with the Educator Performers have been minimal, although they occasionally appear. For instance, after background music was added, each of the twelve Educator Performers had to be individually re-trained to take note of the new steps in the procedures to turn on and off the music. Something as simple as an operating system update to the tablet resulted in a change in the appearance of the user interface, which resulted in concerns for a few of the presenters who were nervous about computers. There have been instances when a presenter has forgotten to turn off the mic to the headset after they have finished a show, which let the audience hear ambient noises around them after they had left the dome. The common solution to these different issues was to update the training materials, and to refresh each presenter with the revised procedures.

IV. SPACE TOURS LIVE! GOES LIVE

On 17 March 2017, *Destination Solar System* switched to two shows daily, with *Space Tours Live!* taking up the remaining two live show spots. The presenters initially offered two different programs, “Cosmic Distances” and “Types of Planets in the Solar System.” Rehearsals had started on the third topic, “Habitability,” which was adopted by only the most experienced of the Educator Performers, who were more comfortable with the advanced content.

Over the next several months, the Educator Performers experimented with their deliveries, and slowly discovered a set of best practices and recommendations, which were reported back to the planetarium team via two different “Show Shop” workshops in the summer of 2017. Some of the difficulties with the initial version of *Space Tours Live!* was due to narratives that were too script-like. The word “script” itself implied text that had to be repeated verbatim by the presenter, whereas *Space Tours Live!* was intended to be more free-form and less confining. To create more satisfying storytelling, Programs staff decided that the introductions and the endings for each story would be scripted, but the middle would be a looser, adaptive narrative, created on the fly by the presenter. As a result, the “scripts” evolved into “programmatic outlines.” Content knowledge was published in separate content sheets for each storyline, emphasizing that even in the training materials, a variety of content could be grafted onto each user-driven story.

The Educator Performers also found that audiences often did not enter the dome excited and ready to offer ideas for places they wished to visit. To get visitors to open up, the presenters now engaged with them as they stood in line waiting to enter the theater. During these 5-10 minutes, the guests connected with the host, learned about the show format, and became primed to be more participatory, instead of waiting to sit and watch passively. Again to emphasize the free-form nature of the experience and move away from a didactic classroom, Educator Performers asked “What are you wondering about?” or “Are there any places in the Solar System that you are curious about?” instead of “Do you have any questions?”

At the start of *Space Tours Live!*, most of the Educator Performers selected “Types of Planets in the Solar System” because they believed the content was easier to learn. The storyline had two main threads, one on terrestrial planets, and the other on gas giants. Visitors were asked to select a planet from each group. Visitor feedback showed that they preferred to have more flexibility in their options. The programmatic outlines were later remediated to give the audience more freedom of choice.

The "Habitability" show was also altered. The first version of the show had the presenter offering up a list of planets within and outside of the habitable zone around the Sun. To the audience, having two broad options again felt like they did not have much of a choice. After further refinements, guests are now given more options, including the ability to visit moons and even the Sun.

Over the summer, one of the Educator Performers started to develop a "Cosmic Collisions" story. This narrative had a variety of different options, and engaged the audience in visual thinking, by asking them to report what they were observing on the dome. This show was immediately successful with both the Educator Performers—four of them picked it up within weeks of the release of its programmatic outline in October 2017—as well as visitors. At this time, the least popular show, "Types of Planets," was retired from the list of offerings.

V. EVALUATIONS

Early feedback from audiences was extremely positive, but anecdotal. During special evening programs when *Space Tours Live!* competed with other live and interactive offerings elsewhere in the museum, the live planetarium show usually ranked first. The first formal evaluation was conducted in May 2018 by DMNS' Audience Insights evaluation team. Ninety-five visitors who had attended six different *Space Tours Live!* shows were surveyed. When asked about the live Educator Performer, the vast majority of audience members "agreed" or "strongly agreed" that the presence of a live facilitator helped them learn more (a combined total of 92% in the two categories), made the show more engaging (94% in the combined two categories), and enjoyable (87% in the combined two categories).

Visitors were also asked to rank the show using the Overall Experience Rating (OER) survey, which was originally developed by and had been used continuously at the Smithsonian Institution for the last 14 years (Pekarik, Schreiber, & Visscher 2018). The instrument uses a five-point Likert scale, with ratings of Poor, Fair, Good, Excellent, and Superior to capture feelings of the overall experience. Its consistent use at all Smithsonian museums to survey over a hundred exhibits and programs provides a stable baseline for the comparison of new programs. Like many other museums (Pekarik et al. 2017), DMNS has adopted OER as a way to inter-compare its exhibits and visitor programs.

Smithsonian's Office of Policy & Analysis found that the fraction of visitors surveyed using OER who ranked an exhibit or program Excellent was typically in the range 40%-60%, whereas the rankings below or above Excellent could vary greatly from one program to the next (Perkarik et al. 2018). The OER is argued to be a better indicator of whether an experience excites the most enthusiastic visitors, because it offers a rating beyond mere Excellent. Based on statistics gathered at Smithsonian museums, the typical fraction of audiences that give the highest Superior ratings is 20%.

DMNS has not gathered as many OER evaluations for any comparisons to be meaningful. But for visitors who saw *Space Tours Live!*, 10% ranked the show as less than Excellent (i.e., Poor, Fair, or Good), while 49% gave it Excellent marks, and 41% ranked it Superior. If like the Smithsonian museums, DMNS programs on average also receive a rating of Superior by 20% of its visitors, then the *Space Tours Live!* Superior score of 41% has an error of roughly 10% at the 95% confidence level.

VI. FUTURE OF SPACE TOURS LIVE!

The current set of storylines for *Space Tours Live!* are fixed for months at a time, since it takes more time and resources to create new stories, program in new visuals, and train the Educator Performers. For future iterations of the program, we are exploring how we can incorporate current science to make the show more topical. This would involve selecting a current news story, and have a procedure in place for scripting, scientific review, adding new content into Uniview, re-programming the Panels interface, testing, and training. Educator Performers would not be expected to integrate this new content into their presentations until they had sufficient practice, and were comfortable telling the new story.

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Teaching Distances to Stars and Galaxies with a Digital Planetarium

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BIOGRAPHIES

Ka Chun Yu has developed real-time interactive planetarium visualization software; been involved in live and pre-rendered fulldome show productions; given hundreds of public lectures, professional development programs, classes, and media appearances; and researched the use of digital planetariums for astronomical and Earth systems education.

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ABSTRACT

Today's planetarium visualization software allows visitors to zoom out into the cosmos, flying at exponentially greater speeds, to propel them from planetary to galactic to extragalactic realms. This feature mimics Ray and Charles Eames' iconic "Powers of Ten" short film, which first introduced audiences to the idea of nested scales in the universe. Following up on our earlier study of this pedagogical approach for distances in the Solar System, we report here on the use of logarithmic zoom visualizations to teach college undergraduate students about the distances to stars and galaxies. Students who viewed immersive visualizations inside a fulldome planetarium showed better performance than control groups which saw the same visualizations on a flat screen in their classroom. The students who visited the dome also had better retention, with their assessment scores dropping less 2-4 weeks after their experience. The long-term retention of students who were taught without the benefit of any computer-generated visuals was similar to students who viewed non-immersive versions of the planetarium visuals in their classroom. We discuss how these and other recent research results suggest strategies for designing planetarium learning experiences for maximum student impact.

I. INTRODUCTION

Scales and distances in astronomy are traditionally difficult to teach because the quantities are far greater than what people can intuitively comprehend (AAAS 1986, Miller & Brewer 2010). When probed to gauge their intuitive understanding of astronomical distances, students ranging from junior high to college tended to underestimate Sun-Earth and Sun-to-nearest star distances (Sadler 1992; Trumper 2000, 2001a, 2001b) with the amount of underestimation increasing for more distant objects like stars and galaxies (Miller & Brewer 2010). Erroneous conceptions about astronomical scale have been found to be resistant to change even after a semester-long undergraduate astronomy class (Zeilik, Schau & Mattern 1998; Kalkan & Kiroglu 2007), which suggest that students hold alternative conceptions prior to their classroom introduction to the topic. Such deeply rooted ideas are based on personal experience or culturally received models, and hence are not easily changed even with instruction. Instead, mental models may be modified only slightly to accommodate teachings to become synthetic models that are a mix of different conceptual frameworks (Posner & et al. 1982, Vosniadou 1992, Baxter 1995). Students may even revert to their prior beliefs even after showing they have a correct understanding for a period of time (Kikas 1998).

Given this situation, the traditional pedagogical approaches for addressing scale in the classroom are problematic. Two-dimensional diagrams (e.g., those found in textbooks; Padalkar & Ramadas 2008) and physical models are the two most common approaches. However, demonstrating proper scale and three-dimensional relationships between the Sun, Earth, and Moon with such materials without introducing new misconceptions can be challenging (Heyer, Slater, & Slater 2013; Eriksson et al. 2014). Astronomical scales range over multiple orders of magnitude, and are thus difficult to reproduce accurately (Dahsah et al. 2012; Guy & Young 2010; Taylor & Lyons 2008). Diagrams may lead students to believe that Earth is the same size or even larger than the Sun (Bakas & Mikropoulos 2003), or that solar and lunar eclipses occur every month (Rosvick 2008). Limitations of these traditional methods has led us to re-purposed two other techniques for the digital planetarium.

Visualization software in modern digital fulldome planetariums are a powerful tool for demonstrating astronomical sizes and distances, by allowing operators to zoom through multiple "powers of ten" of scale (Klashed, Emmart, & Ynnerman 2004). This navigational paradigm is influenced by the classic short film of the same name by Ray and Charles Eames (Eames & Eames 1977; Morrison & Morrison 1994). Students who watch this film have a better understanding of scale and powers of ten, while teachers also view the film positively as an instructional tool (Jones et al. 2007).

Another pedagogic technique for teaching astronomical scale is to use a model Solar System, the largest of which are permanent installations that have to be traversed by walking (Pompea 2000; LoPresto, Murrell, & Kirchner 2010). Physically experiencing a large space—by traveling through it or noticing how the landscape changes—has been cited by adults as helping to develop their sense of scale as adolescents (Jones & Taylor 2009). Time spent in transit—from running across a football field to driving for several hours for a family vacation—has also been recalled as memorable events that led to a personal understanding of scale (Tretter et al. 2006). Some evidence exists that traversing physical (Lelliott 2010; LoPresto et al. 2010) and virtual Solar System models (Yu, Sahami, & Dove 2017) can be effective for teaching astronomical scale.

We have previously looked at the use of digital planetariums for understanding astronomical scale inside the Solar System (Yu et al. 2017). We developed virtual measuring tools in SCISS AB's Uniview visualization platform to help students keep track of distances between objects, and to recognize the scale being visualized while undergoing a powers of ten zoom. We also tried to replicate the temporal experience of traveling long distances as a proxy representation of the large distances between planets in the Solar System. In that earlier study, not only did students who saw a short presentation in the planetarium have greater learning gains than their counterparts who saw the same presentation projected onto a flat screen in the classroom, but they also had better retention over time. In this current paper, we expand on this prior work by looking at the use of a digital planetarium to teach distances to nearby stars and to other galaxies outside of our Milky Way.

II. METHODOLOGY

Undergraduate students enrolled in semester-long introductory astronomy classes (from fall 2005 to spring 2010) at a medium-sized urban university were the subjects in this study. Before the experiment started, we conducted oral interviews on students prior to their instruction in two introductory astronomy classes, to probe their understanding of the relative sizes and distances between stars and galaxies. Informed by these interviews and prior research, we created new lecture outlines to address common alternative conceptions about astronomical scale.

Seventeen classes taking part in the quasi-experimental study were divided into three groups. Students in three Group I (GI) classes saw no visualizations; five Group II (GII) classes were exposed to instruction using planetarium visuals shown on a flat classroom screen; and nine Group III (GIII) classes were taught using immersive versions of the same visualizations projected in the Gates Planetarium at the Denver Museum of Nature & Science. The total number of students participating in the study were 157, 307, and 511 in GI, GII, and GIII, respectively. The unequal number of classes in each Group was chosen to reduce the size of the confidence intervals in the analyzed results for the classes receiving the experimental treatments.

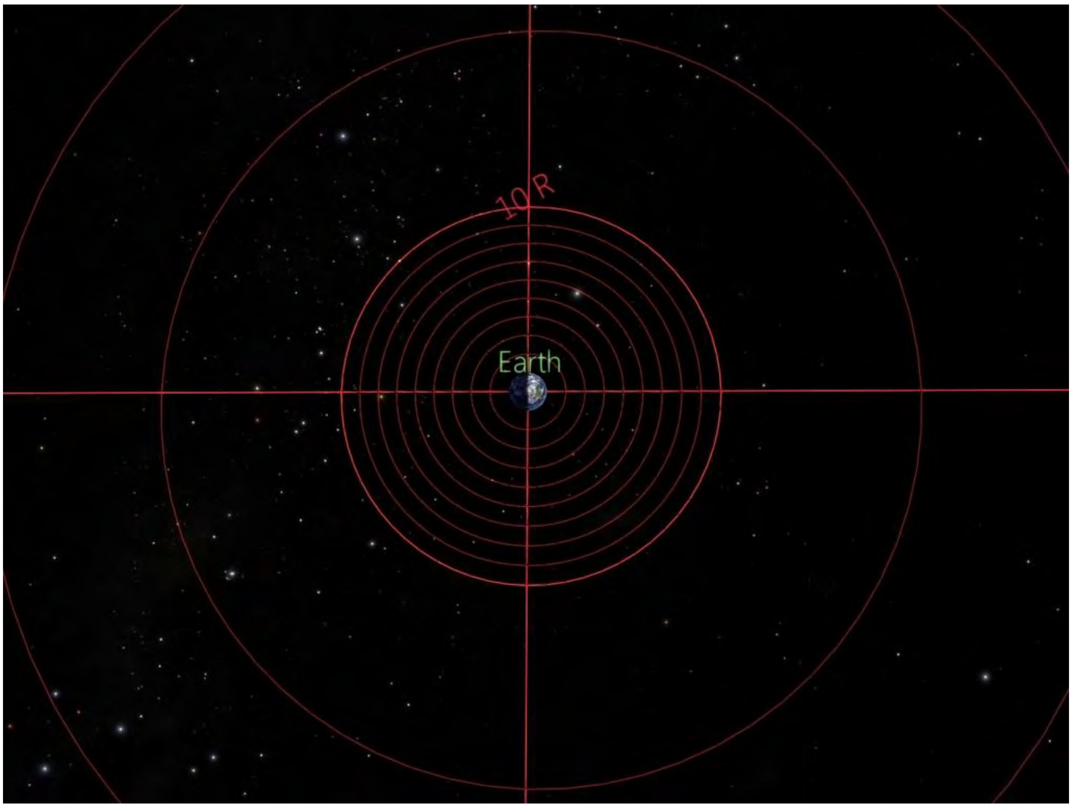

Figure 1 – A two-dimensional radial grid centered on Earth, with the initial grid spacing set to 1 Earth radius, and increasing by a factor of 10 with each order magnitude of increase in distance from Earth.

The two instructors taught almost equal numbers of classes in each Group. All of the classes used the same textbook and had the same lectures for the topic of distances to stars and galaxies, following the same outline and at the same pace. To avoid confounding the impact of the visualizations, no other animations were shown in any of the classes. GI students were exposed to classroom lectures supplemented by a PowerPoint presentation containing still diagrams and text. More details about the classroom and planetarium environments, the level of student participation, and the logistics of GIII class visits to the planetarium can be found in Yu et al. (2015). For the GII and GIII classes, the Uniview planetarium software was used to generate the visuals for flight through the virtual universe. A skilled navigator was present in the classroom or in the planetarium to pilot the software while following along with the instructor, who could concentrate on teaching.

In our prior work (Yu et al. 2017), we tested two innovations for teaching Solar System scale: a virtual grid to quantitatively show distances based on the powers of ten zoom, and mimicking the traverse of a physical Solar System scale model by flying at a constant velocity. For the former, a two-dimensional lattice is rendered centering on and extending from an object of interest, such as the Earth, and consisting of concentric rings with each ring equal to Earth's radius (Figure 1). For each factor of 10 distance from Earth, the grid size increases by 10, so that the nested rings can be used to describe logarithmically increasing distances (multiples of Earth radii by factors of 10, 10^2, 10^3, etc.). When oriented to intersect Earth's Moon or the Sun, the grid effectively becomes a ruler for measuring the Earth-Moon and Earth-Sun distances in units of Earth radii. A grid based on the Astronomical Unit can be used to mark distances between planets in the Solar System. Finally, we replicate the experience of walking through a Solar System model by flying at a constant speed inside the Solar System[1]. We suspect that the virtual camera traveling for several minutes at a constant superluminal speed would be memorable to the class, if only because space travel is perceptibly monotonous when there is no change in the surrounding star field. This length of transit time can be used to emphasize the vast distances involved when talking about astronomical scales.

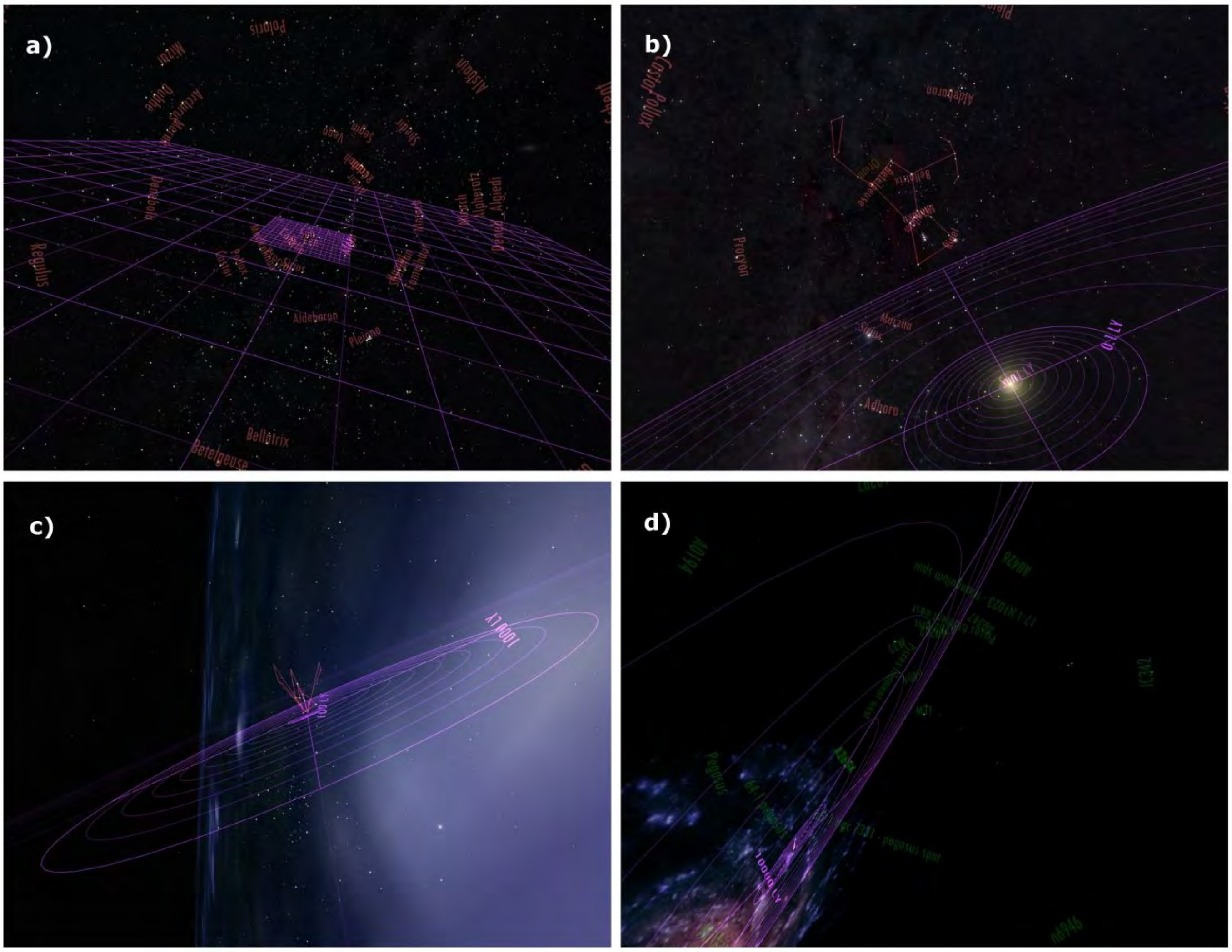

Figure 2 - Screenshots from Uniview showing exponentially growing grids to measure distances at different scales.

For this study, we use similar grids for measuring distances, but adopt grid intervals in light months and light years. The visualizations start with the virtual camera flying at a constant rate from the Sun to Alpha Centauri, and then into the Local Solar Neighborhood (about 50 light years) while a logarithmically-growing Cartesian grid marks the distances (Figure 2a). Next, the camera is placed back at the Sun, and oriented towards the constellation of Orion; the Uniview operator shifts the

[1] The typical way to navigate in Uniview and other astronomy simulation platforms is via velocities that exponentially increase as you move further from a central reference point.

camera laterally 10 light years to the right and left, creating a parallactic shift in the star field, including most notably, Sirius located at a close 8.6 light years away (Figure 2b). The camera then pulls 1000 light years back from the Sun, which allows the structure of the Milky Way Galaxy to become visible (Figure 2c). With a light year grid toggled on, the camera spends a full minute flying at a constant speed towards the Andromeda Galaxy to emphasize another increase in power of ten of scale (Figure 2d). The class is flown out to view additional spiral (M33, M51) and elliptical (M87) galaxies, before a reverse powers of ten zoom back to the Sun.

The authors and instructors (all of whom have extensive teaching and research experience in astronomy) developed a set of multiple choice questions for use in the weekly student assessments. A set of eight questions was asked roughly the same week as the instruction on distances to stars and galaxies (*Cont*), and five questions tested retention of knowledge after instruction (*Post*). Because this was a one-semester class covering astronomy subjects both inside and outside the Solar System, the topic of distances to stars and galaxies did not appear until towards the end of the course, meaning there was a short gap of 2-4 weeks between the *Cont* and *Post* assessments.

III. RESULTS

In Table I, we present the *Cont* and *Post* assessment scores (*M*) for the three different treatment groups, along with the standard deviation (*SD*), standard error (*SE*), and 95% confidence intervals (*CI*). The number of students, *n*, represents only those who were present for a particular weekly assessment, and therefore, whose scores contributed to this analysis. Figure 3 plots the mean scores for the two assessments and the three different Groups, with the 95% confidence intervals shown as error bars.

Table 1 – Assessment Scores in Percentages

		Average Scores	
		Cont	*Post*
Group I	*M*	70.8%	48.3%
	n	97	115
	SD	33.1%	32.3%
	SE	3.4%	3.0%
	95% *CI*	6.7%	6.0%
Group II	*M*	57.0%	50.0%
	n	265	243
	SD	36.7%	33.8%
	SE	2.3%	2.2%
	95% *CI*	4.4%	4.3%
Group III	*M*	62.3%	58.9%
	n	373	345
	SD	31.1%	29.3%
	SE	1.6%	1.6%
	95% *CI*	3.2%	3.1%

A one-way ANOVA test with a Welch correction for non-homogeneity of variances (Welch 1951) show that the mean scores for the *Cont* and *Post* assessments all significantly differed each other within each of the three Groups (GI: $F=26.77, df_{1,2}=2,206.8, p<0.01$; GII: $F=7.17, df_{1,2}=2,509.1, p<0.01$; GIII: $F=6.00, df_{1,2}=2,759.8, p<0.01$). We follow-up with a Games-Howell post-hoc test to compare the means between the three Groups. This statistical test is valid for distributions with unequal sample sizes and unequal variances (Maxwell & Delaney 2004), and reveals that only the means for the *Cont* assessments for GII and GI significantly differ from each other ($M_{GII}=57.0\%; M_{GI}=70.8\%; t=3.42; df=158.2; p<0.01$). The GIII and GI means are not significantly different at the 5% level ($M_{GIII}=62.3\%; M_{GI}=70.8\%; t=2.28; df=143.3; p=0.06$), and neither are the GIII and GII means ($M_{GIII}=62.3\%; M_{GII}=57.0\%; t=1.93; df=508.3; p=0.13$). However for the *Post* tests, GIII differs significantly from GII ($M_{GIII}=58.9\%; M_{GII}=50.0\%; t=3.32; df=473.2; p<0.01$) and GI ($M_{GI}=48.3\%; t=3.10; df=180.6; p<0.01$).

The much stronger GI scores in the *Cont* assessment is not immediately explicable. However, this effect has also been seen in the other astronomical topics taught and investigated in our research for the same student population, where a high *Cont* score is followed by a large drop in performance by the time of the *Post* assessment (Yu et al. 2016). One possible explanation is that this behavior is due to GI consisting only of three control group classes, with the total number of students less than half that of the other two Groups. The control group classes could be outliers due to their smaller sample, or to factors related to the fact that they were all taught during the same semester.

IV. DISCUSSION

In the assessments immediately after instruction, the students who visited the planetarium (GIII) do better than those who viewed visualizations in the classroom (GII), but do not perform as well as the GI controls. However, by the post-instruction assessments, the GIII students with the immersive fulldome experience had smaller drops in their mean scores, showing better longer-term retention than either the GI or GII students. The 9-10% better mean scores of the GIII students compared to the other two Groups is significant. Like our previous work (Yu et al. 2015, 2016, 2017), the current study shows the effectiveness of the fulldome planetarium. These results also support our previous work on the topic of scale of the Solar System (Yu et al. 2017), where we first used a logarithmically scaling ruler and simulated flight at a constant speed to mimic the time spent traversing a physical scale model. Since the treatment combines both of these techniques, further research is necessary to disentangle how much each method contributes to student understanding.

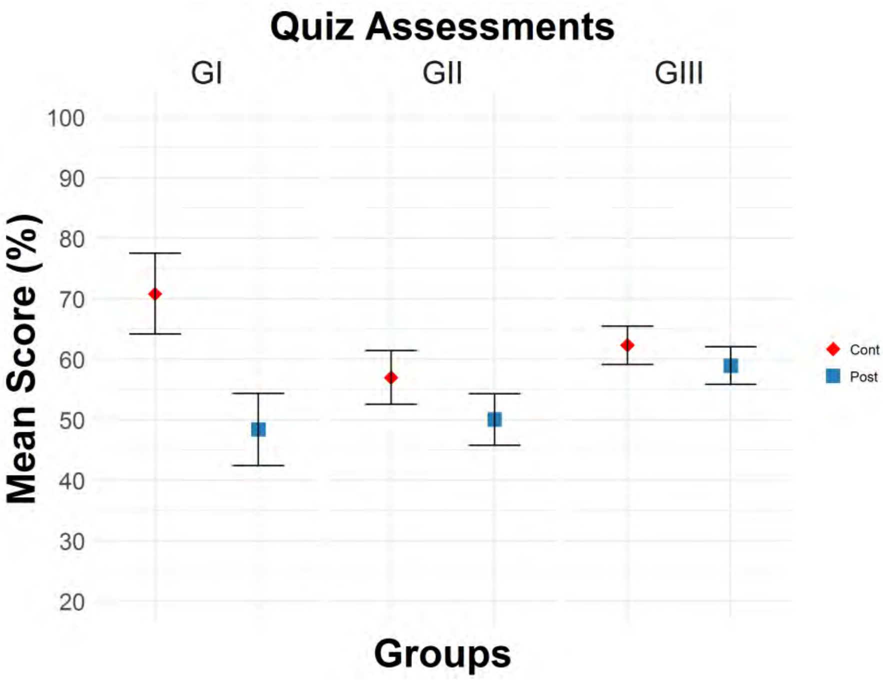

Figure 3 – The mean scores for the *Cont* and *Post* assessments of the distance of stars and galaxies topic for the three experimental groups with 95% confidence intervals shown as error bars.

Even though both GII and GIII see the same visualizations, the fact that two Groups have such different results is curious. We have tried to control for as many variables beyond the classroom and dome environments, by having the same two instructors teaching classes in each Group, following the same outline, at the same pace, and using the same set of visuals. We have argued that wide fulldome displays result in substantial benefits for students, especially when compared to their classroom flatscreen counterparts (Yu et al. 2015). Depending on where the student is seated in our study, the flat classroom display subtends a field-of-view as small as 11° but no more than 29°, compared with 180° for the planetarium dome. Therefore, the students in the planetarium have a better view of the visuals compared to their classroom counterparts. The highly immersive dome display may also offset cognitive load when the topic of instruction requires spatial understanding. However, none of the lessons in the topic of Solar System, galactic, or extragalactic scale requires any awareness or understanding of objects located in different spatial directions.

Yu et al. (2016) speculate that the imagery that extends across the wide field-of-view display of the planetarium stimulates viewers' far peripheral vision, which, combined with the physically larger screen size of the dome, results in greater attention by the audience to the lecture. In that earlier study, the audience in the dome would see individual moons, the orbits of nearby and distant satellites, and object labels shift and move in all directions as the virtual camera flew from one location to the next. For the results here, a similar experience during instruction in the dome would occur, when the field of stars (or galaxies when outside the Milky Way) shifted along with the logarithmic measuring grid as the camera moved. When the operator flew forward or backward, the population of visible objects would drift in and out of a viewer's peripheral vision in a steady optic flow.

Since flying through star fields is a common, visual trope in both pre-rendered and real-time fulldome astronomy programs, our results suggest that this navigation method actually has educational impact on learning in the dome. In conclusion, we suspect that the mere act of flying through three-dimensional distributions of objects stimulate the far peripheral vision in viewers, leading to subconscious, but significant increases in attention. These results are also consistent with other studies that report greater benefits for those who viewed planetarium visuals compared to those who saw flat screen versions of the same (Heimlich et al. 2010; Zimmerman et al. 2014).

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